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Arts, Sciences, and Literature.

BY

ABRAHAM REES, D.D. F.R.S. F.L.S. *S. Amer. Soc.*

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CYCLOPÆDIA:

OR, A NEW

UNIVERSAL DICTIONARY

OF

ARTS and SCIENCES.

Forge

FORGE, properly ſpeaking, is any kind of furnace, the heat of which is afforded by the action of bellows. The term, however, is now more particularly applied to the common ſmith's forge, and to the forge uſed for the manufacture of bar iron. For a deſcription of the latter, ſee IRON.

A peculiar ſpecies of forge is alſo uſed for the manufacture of ſhear ſteel; for an account of which, ſee STEEL. The common ſmith's forge requires bellows of different kinds and ſizes, agreeable to the nature of the work.

The double bellows are chiefly uſed for the working of iron, and ſingle ones for ſteel. The double bellows are apt to blow ſome time after the workman takes out one of his irons; and as in working ſteel, the heat is leſs than that employed for iron, the rod of ſteel, if left in the fire, would be often liable to be burned, as the workmen term it The ſingle bellows are, therefore, better adapted for this work, becauſe the blaſt does not continue after the workman leaves the bellows.

The fire-place is generally a flat hearth, nearly on a level with the blaſt, on which the fuel is placed, which moſtly conſiſts of the coaks of pit-coal. In ſmithery, however, and more particularly for the working of ſteel, the coal ſhould be carefully ſelected, as free from pyrites as poſſible, as the ſulphur of that ſubſtance is found to be very injurious to the metal. In all caſes where welding is required, the ſulphur totally prevents the adheſion. If pyrites ſhould by accident get into the fire, the beſt means to get rid of it is to throw a quantity of iron-filings into the fire, which immediately takes up the ſulphur.

After the coaks have been uſed for ſome time, the pieces become exceedingly ſmall, and are ſo light as to be blown away by the bellows, ſeparating the fuel from the iron. This inconvenience is removed by taking away theſe ſmall particles from time to time. It, however, may be much eaſier removed by a contrivance which is not in general uſe. This is effected by making the bed of the hearth a grate, about four inches below the level of the blaſt. The ſmall duſt, paſſing through the grate upon an inclined plane, is carried away, leaving nothing on the hearth but the proper fuel.

In moſt of theſe forges, particularly where great heat is required, the nozel of the bellows is not preſented to the fire. A thick iron tube is placed between the bellows and the fire, called the tuiron. It is funnel-ſhaped at the end next the bellows, for the reception of the nozel of the bellows; and has a cylindric hole, from about the middle to the oppoſite end, a little leſs than the aperture at the nozel of the bellows.

Before means were contrived of preventing the tuiron from being raiſed above a certain temperature, it was very ſpeedily worn out by the heat and the oxydation of the iron. This evil has been removed by the invention of what is now called the water-tuiron. It conſiſts of ſomething like the common tuiron, having a crooked tube paſſing through the body of it. One end of the tube, at ſome diſtance from the tuiron, is inſerted into the bottom of a tub, filled with water; the other end coming from the tuiron paſſes over the top of the tub: ſo that the cold water has conſtant acceſs to the body of the tuiron, which the heat of the fire raiſes into vapour. This vapour paſſes up the other tube, which condenſing, is diſcharged into the tub. By this means, it is evident that the tuiron can never much exceed the heat of boiling water. This contrivance prevents a much greater evil than the deſtruction of the tuiron. The oxyd of iron, which is conſtantly formed from the heated iron, combining with the earthy matter of the coal, forms a very fuſible ſcoria, which, if the tuiron were not kept cool, would be apt to adhere to it, and ſtop up its aperture. This ſcoria may be eaſily diſcharged through the grate of the hearth, which would at any rate be an interruption to the blaſt.

The large quantity of oxygen conſtantly blown into the fire, upon the iron, at ſo high a temperature, cauſes a very rapid oxydation of the metal. This oxyd has ſome tendency to vitrification, and conſequently to prevent the iron, in ſome meaſure, from the future attacks of oxygen. Since, however, ſilex forms a very fuſible vitreous compound with the oxyd of iron, the ſmith is in the habit of uſing the powder of any ſtone of a ſandy nature. When the iron becomes nearly of a welding heat, he takes it out to immerſe it in the powdered ſand. A thin fluid ſubſtance is immediately ſeen to flow over the heated ſurface, which defends the metal from the oxygen. In the welding of one piece of iron to another, the uſe of ſand is highly important, and more particularly in welding ſteel to iron. When the two ſurfaces are brought together, the oxyd of iron, with the flint, is removed by reaſon of its gre t fluidity. If, however, the oxyd were not rendered thus fluid, it would remain and prevent the adheſion of the ſurfaces.

Lead is found to be very injurious to the ſmith's fire; it combines with ſomething on the ſurface of the iron, which makes it unfit for welding. Its preſence is eaſily known, as the iron affected with it makes a brown mark upon the

anvil. The ſtrongeſt heat of a forge is at about two inches from, and a little above the aperture of the tuiron.

A forge is alſo uſed by braziers, copper ſmiths, and in the plated manufactories. This conſiſts of a hearth like the ſmith's forge, and a pair of bellows. The fuel is moſtly coak, but ſometimes for particular purpoſes charcoal. It is uſed for annealing their metal previous to working it, and alſo for ſoldering.

The forge fire is not well calculated for the fuſion of metals, ſince the ſide of the crucible next the blaſt is liable to be cooled, which generally cauſes it to break. The portable blaſt furnace is however better adapted than the common forge, as the air is introduced at bottom, like the common air furnace. See FURNACE.

Forging conſiſts in changing the form of ſuch malleable metals as may have been heated for that purpoſe in the fire of the forge, by means of the hammer and other inſtruments uſed in ſmithery.

Several of theſe proceſſes are carried on by machinery worked by water or ſteam. In the manufacture of bar iron, very large maſſes of this metal, called blooms, are drawn into bars by an immenſe hammer, worked by a water wheel, or the ſteam-engine. See IRON.

The forging of ſcythes is alſo performed by ſimilar power, which by the workmen is called ſkelping. See SCYTHE.

Forging, however, more properly belongs to the forming of various utenſils from iron, and other malleable metals.

The anvil, on which the metal is laid, conſiſts of a large maſs of wrought iron, faced with hardened ſteel, and ground ſmooth on the ſurface. The hammers are of the ſame materials, and are of different ſizes, agreeable to the nature of the work. If the work is heavy, beſides the perſon who holds the ſubſtance to be hammered, a ſecond, and ſometimes a third and fourth perſon ſtrike in turns at the heated body. If the body requires to be made round, inſtruments called *ſwages* are employed. They conſiſt of two maſſes of iron faced with ſteel, and hardened, one lying upon the anvil, or faſtened into a groove in the anvil, and the other held in the hand, by means of a piece of hazel ſtick twiſted round it. In the faces of each of theſe ſwages a proper ſized groove is made, which, for ſwaging round bodies, is a ſegment of a cylinder. The body to be ſwaged being laid upon the lower one, the upper ſwage is placed upon it, on which a perſon ſtrikes with a large hammer, while the body to be made cylindrical is turned round. A variety of other inſtruments are uſed according to the nature of the work to be done. Iron admits of being *forged* with greater facility than ſteel, as it is much ſofter, and can be heated to a much greater heat, which ſtill makes it ſofter. Indeed iron is generally heated to a welding heat, in order that its parts, which are frequently looſe and unconnected, may be made ſound.

Copper may be forged into any ſhape, but will not bear more than a red heat, and of courſe requires to be heated often. The bottoms of large boilers are frequently made by a large forge hammer worked by machinery. The bolts of copper uſed for ſhips, and other purpoſes, are moſtly made by the hammer. Silver, gold, and platina will alſo admit of forging into any form. Of the former metal, ſilver knives are made very neatly by the hammer. The heat at which it is worked ſhould be barely that of ignition.

It is remarkable that alloys of the malleable metals, although very malleable when cold, will not bear the hammer when heated.

FORGE is alſo uſed for a large furnace, wherein iron ore, taken out of the mine, is melted down.

But this is not ſo properly called a forge as a *furnace*; which ſee.

FORGE is more properly uſed for another kind of furnace wherein the iron ore, melted down and ſeparated in a former furnace, and there caſt into ſows and pigs, is heated; and fuſed over again, and beaten afterwards with large hammers, and thus rendered more ſoft, pure, ductile, and fit for uſe.

Of theſe forges there are two kinds, which the iron ſucceſſively paſſes through, before it comes to the ſmith.

The firſt is called the *finery*, where the pigs are worked into groſs iron, and prepared for the ſecond, which is called the *chafery*, where it is farther wrought into bars fit for uſe.

FORGE-*mills*. See MILL.

FORGE-*volant*, or *Flying forge*, means ſuch an arrangement of the ſeveral implements and materials, neceſſary for the eſtabliſhment of a ſmith's forge, within a cart or waggon, as may qualify it to accompany an army during a campaign, with the ſame facility as the ſeveral carriages appertaining to the train of artillery.

It will be immediately underſtood, that much contrivance, and great attention to regularity, are needful to accompliſh and preſerve ſo eſſential a purpoſe; the more ſo, as the whole weight of the forge and its ſupplies of fuel, &c., ſhould not exceed half a ton when conveyed in a cart; nor a whole ton when carried in a waggon. The beſt mode is to place the anvils and their blocks in ſuch a poſition as to balance well, but to be eaſily lifted in and out. For minor purpoſes two or three ſmall anvils may be attached temporarily to the hinder tranſom of the cart-body. There ſhould be a water trough, a furnace, and a pair of bellows, all within a frame of iron plate, properly rivetted and cloſed with hard ſolder, ſo as to be firm, and to prevent latent ſparks from ſetting fire to the machine, or to its contents. The tail-board ſhould let down to a level with the bottom of the cart, and be ſuſpended in that direction by ſtrong ſegments of iron; ſo as to be well fixed, and to reſiſt preſſure either upwards or downwards; the ſides around the furnace and bellows ought to be divided into compartments for the reception of fuel, (generally charcoal,) ſufficient for immediate ſervice, and for the aſſortment of nails, ſcrews, clouts, ſhackles, pins, nuts, horſe ſhoes and nails, bridle chains, buckles, &c., in ſmall quantities, ſo that any thing wanting immediate repair may be fitted without the ſmalleſt delay.

Every forge ſhould carry implements ſufficient to employ forty men; of whom two ſhould be fire-men, ſix ſledge-men, ten light hammer-men, two ſcrew and nut-men, and the reſidue, file-men, or workers on cold metal. If the apparatus be carried in a waggon that can contain two double forges, or furnaces, double the number of men may be employed; ſmall anvils, in either caſe, as alſo vices, being made to ſcrew, or to hook, on to the ends of the ſeveral projecting tranſoms, and even to the naves of the wheels, of which the iron tires become uſeful for light hammer work. The total weight of a forge-waggon, excluſive of its contents, ſhould never exceed 15 cwt. In our arſenals they are made even lighter, their average being 13 cwt. 2 qrs. 14 lbs. Being rated with what are called "Park carriages," it is neceſſary they ſhould conform as nearly as may be practicable with others of their claſs, and be drawn by the number of horſes, &c. uſually employed for light machines.

FORGE *for red-hot balls*, is a place where the balls are made red-hot before they are fired off: it is conſtructed about five or ſix feet below the ſurface of the ground, of ſtrong brick-work, and an iron grate, upon which the balls are laid with a large fire under them.

Forth and Clyde Canal

Forth and *Clyde canal*, is a navigable cut, which, connecting the rivers Forth and Clyde, forms a junction between the German ocean and the Irish sea. The utility of conjoining large rivers, for the purpose of extending their navigation, must be obvious to every reflecting mind, and in no instance did the geographical features of the country, and the circumstances which imperiously called for the execution of such a work, appear more striking than in this The two rivers appeared to look with wishful eyes towards each other, and a natural passage presented itself through the mountains for conducting the union canal. Previous to this being made, the trade of this possessed no channel with the other side of the island, but by immense maritime distance round the Land's End; or by the less circuitous route, but dangerous passage of Pentland frith. Such an idea was conceived so early as the reign of Charles II., and the scheme met with some consideration; but that was not an age for this kind of national improvement. It then lay dormant till the year 1723, when a survey was made of the line of country by Mr. Gordon; still the undertaking was declined by the consideration of the expence. It was again revived in 1762; and a survey made by a Mr. Mackell, and another by Mr. Smeaton in 1764. From these surveys the practicability of the plan was ascertained, but its eligibility was yet questioned on the ground of the estimated expence, eighty thousand pounds. In the mean while a smaller canal was projected to extend from Glasgow to the Forth; parliament, however, refused to sanction the scheme on account of the smallness of the scale. Mr. Smeaton was then called in again to make a survey and estimate for cutting a canal, of such a breadth and depth, as would admit coasting vessels to pass from sea to sea. A subscription was accordingly opened, a bill obtained for leave to execute the plan, and the whole being placed under the direction of the able engineer who surveyed the ground, the undertaking commenced on July 10, 1768. After expending 150,000*l.* and overcoming difficulties which seemed at first insurmountable, it was rendered navigable as far as Stockingfield, where a branch, called Monkland, extends to the collieries to the east of Glasgow. The subscription and an additional loan having been exhausted, the work was here stopped, and in this state it remained till the year 1784, when the company, having obtained 50,000*l.* by forfeited estates, and an act of parliament for varying the line, Mr. Robert Whitworth, being appointed engineer, began to prosecute with great vigour and effect the further execution of the original plan. On the 28th of July, 1790, this immense undertaking was completed, and the navigation opened from sea to sea. Thus, with the aid of the collateral branch, a communication is formed between the great emporium of the north, Glasgow, and both sides of the island. The whole length of the canal is thirty-five miles from the mouth of the river Carron, to Dalmoreburn-foot, on the banks of the Clyde; rising and falling 160 feet, by means of 39 locks. In its course it passes over rocks, through precipices, deep mosses, over quick-sands, and in places is guarded by banks twenty feet high; crosses two considerable rivers, the Kelvin, and Luggie, with numerous rivulets and streams, by 10 large, and 33 smaller aqueducts or water bridges. That over the former river is a grand object, consisting of several arches, the centre one of which is 90 feet, forming an arcade 420 in the span in length, and 65 feet high. Various roads also traverse the canal by the aid of 33 draw-bridges. The dimensions of it, though greatly contracted from the original design, are far superior to any work of the kind in South Britain. The English canals are in general from three to five feet deep; from 20 to 30 feet wide; and the lock gates from ten to twelve feet; sufficiently capacious however to answer the purposes of inland carriage, from one town to another, for which they were exclusively designed. The following particulars will enable the reader to institute a comparison.

		Feet.
The medium width of the surface	-	56
Do. of the bottom	- -	27
Depth on the average from sea to sea		8
The fall of each of the 39 locks		8
The breadth of each lock	-	20
The length of do. between the gates		74

The contrivance for supplying the canal with water was alone a difficult and arduous undertaking. No less than six reservoirs were found expedient; one near Kylsith covers a surface of 50 acres of land; another consists of 70; and the whole occupy about 409, containing by measurement 12,679 lockfulls of water. The expence of the whole concern amounted to 300,000*l.* The toll for the whole line is 5*s.* 10*d.* per ton; against this is to be placed safety, time gained in passing from coast to coast; and the difference in insurance, that usually in time of war being in coasting it from 15*l.* to 20*l*; and by the canal, 5*l.* Phillips's General History of Inland Navigation, and Sinclair's General Statistical Account of Scotland.

Foundery

FOUNDERY, or Foundry, the art of melting and caſting all ſorts of metals; particularly braſs, iron, bell-metal, &c. The word is alſo uſed for a place, or work-houſe, furniſhed with furnaces, or forges for this purpoſe. A foundery, in the iron manufacture, is almoſt always connected with the blaſt furnace where the metal is ſmelted from the ore; from this circumſtance we ſo frequently find the ſmelting furnace and its appendages termed a foundery, though in reality the word ſhould be confined to the building for caſting up the metal manufactured at the former; it is there termed the caſting-houſe, (ſee the article Blast *furnace.*) The caſting-houſe, or foundery, is ſituated on one of the ſides of the furnace, the ſurface of its ground about two feet below the level of the bottom of the hearth of the furnace. The floor of the foundery ſhould be about ten feet deep, with the loamy ſand, as mentioned in the article Casting, of which the moulds are formed; this is for the convenience of burying large moulds beneath the ſurface, ſo that the metal may be conveyed into them by ſmall channels or ſoughs hollowed out in the ſand. A moſt important circumſtance to be attended to is, that the foundery is well drained of water, as any dampneſs in moulds would produce the fatal exploſions by the ſudden expanſion of the ſteam. When the hot metal is introduced into a wet mould, many ſerious accidents have ariſen from a want of attention to this very neceſſary circumſtance; in ſuch a caſe, the moulds are burſt aſunder, the ground torn up, and the fluid metal thrown in every direction amongſt the workmen, occaſioning as much damage from its projectile force, as from its great heat, to thoſe on whom it falls. Every foundery is furniſhed with a crane, or ſometimes two, placed ſo as to command the whole for the convenience of taking up and removing heavy pieces of caſting from any part of the place. At Buttlerby iron works, Derbyſhire, we noticed an excellent crane for a foundery; the pulley from which the goods are ſuſpended is not fixed to the end of the gib, but ſlides upon it by means of a rack moved by a pinion, which can be turned with eaſe by the workman, ſo as to give the crane any range within its reach; and it can take up weights as well at ſix feet from the centre as at ten, which renders it a moſt uſeful implement in ſuch a ſituation, where the crane is frequently uſed to lower down moulds upon one another in a perpendicular direction, as mentioned in the article Casting.

The moſt complete founderies are provided with two or more air or reverberating furnaces, (ſee Furnace,) in which the metal is melted occaſionally, either when the metal contained in the blaſt furnace is not ſufficient, or when the quality of the metal made there is not proper for caſting, owing to its containing too much or too little carbon, and it requires mixing with better or worſe metal to render it fit for the purpoſe.

They have alſo two or three cupolas, or ſmall blaſt furnaces, to melt ſmall quantities of metal, particularly when it is wanted in haſte, as the reverberatories are much longer in filling their charge of metal, though it is in greater quantity; but the latter does not ſo well anſwer the purpoſes of the iron founder, becauſe it would require ſo great a ſtock of flaſks and implements to make moulds to receive a large quantity of metal; for this reaſon they ſeldom employ the reverberatory but for large articles which require the whole charge; ſmaller goods are caſt from the cupolas.

In the foundery of a blaſt furnace, a pit is ſunk at a convenient diſtance from the furnace, and the moulds for pipes, and other ſimilar articles, are placed vertically in it, within reach of the crane: the metal is conveyed by gutters or ſoughs from the furnace, and a ſmall iron trough, filled with ſand, leads the fluid metal into each of the moulds; theſe are a conſiderable improvement on the old method of burying them in the ſand, in the ſaving of labour and time; the flaſks are made of caſt iron for the purpoſe.

It has of late become a practice at our moſt extenſive

founderies, to fubftitute fand for loam caftings in many cafes where a great number of articles of one kind are to be caft, fo that the expence of the flafks is not an object of importance; where the articles are intricate, the fand is wetted fo much to render it fufficiently adhefive, that it is neceffary to dry the moulds to avoid the danger of an explofion: for this purpofe large ftoves are ufed, and carriages adapted, on which to convey a great number of moulds into the ftove at once, and when fufficiently dry, which generally happens in about half an hour, they are withdrawn, and a new fet placed on the carriage.

A foundery is generally provided with a boring-mill for forming the internal furface of the cylinders caft for fteam-engines, &c. (fee CYLINDER *boring*), and the fame machinery turns large lathes, for turning heavy mill axes, piftons, rollers for fugar-mills, and laminating rollers; the fame mill gives motion to all thefe, and alfo blows the cupolas, though at a blaft-furnace thefe are fupplied by a fmall pipe from the great blowing-engine for the furnace.

FOUNDERY *of fmall works, or the manner of cafting in fand.*—The fand ufed by the founders, in cafting brafs, &c. is yellowifh, and pretty foft; but, after it has been ufed, it becomes quite black, becaufe of the charcoal-duft ufed in the moulds. Every time they would ufe this fand, they work and tew it, feveral times over, on a board about a foot fquare, placed over a kind of trunk, or box, into which it may fall from off the board. This tewing is performed with a roller, or cylinder, about two feet long, and two inches in diameter; and a kind of knife, made of the blade of a fword: with thefe two inftruments they alternately roll and cut the fand; and, at length, turn it down into the box or trough underneath.

Then, taking a wooden board, or table, of a length and breadth proportional to the quantity of things to be caft; round this they put a frame or ledge; and thus make a fort of mould. This mould they fill with the fand before prepared, and moderately moiftened: which done, they take wooden, or metalline models, or patterns of the things intended to be caft: apply them on the mould, and prefs them down in the fand, fo as to leave their form indented; along the middle of the mould is laid half a little cylinder of brafs, which is to be the mafter jet, or canal for running the metal; being fo difpofed, as to touch the ledge on one fide, and only to reach to the laft pattern on the other: from this are placed feveral leffer jets or branches, reaching to each pattern, whereby the metal is conveyed through the whole frame.

This firft frame being thus finifhed, they turn it upfide down, to take out the pattern from the fand; in order to which, they firft loofen them a little all round, with a fmall cutting inftrument.

After the fame manner they proceed to work the counterpart, or other half of the mould, with the fame patterns, in a frame exactly like the former; excepting that it has pins, which, entering holes correfponding thereto in the other, make, when the two are joined together, the two cavities of the pattern fall exactly on each other.

The frame, being thus moulded, is carried to the founder, or melter; who, after enlarging the principal jet, or canal, of the counter-part, with a kind of knife, adding the crofs jets, or canals, to the feveral patterns in both, and fprinkling them over with mill-duft, fets them to dry in an oven.

When both parts of the mould are fufficiently dried, they join them together, by means of the pins; and to prevent their ftarting, or flipping afide, by the force of the metal, which is to come in flaming hot, through a hole contrived at the mafter-jet, they lock them in a kind of prefs, either with fcrews; or if the mould be too big for this, with wedges. The moulds, thus put in the prefs, are ranged near the furnace, to be in readinefs to receive the metal as it comes out of the crucible.

While the moulds are thus preparing, the metal is put in fufion in an earthen crucible, about ten inches high, and four in diameter.

The furnace wherein the fufion is made is much like the fmith's forge; having, like that, a chimney, to carry off the fmoke; a pair of bellows to blow up the fire; and a hearth where the fire is made, and the crucible placed. It is the ufe of this hearth, that chiefly diftinguifhes the furnace from the forge.

In the middle thereof is a fquare cavity, ten or twelve inches wide, which goes to the very bottom: it is divided into two, by an iron grate: the upper partition ferves to hold the crucible, and the fuel, and the lower to receive the afhes.

When the fuel, which is to be of dry wood, is pretty well lighted, they put the crucible full of metal in the middle, and cover it with an earthen lid; and, to increafe the force of the fire, befides blowing it up with the bellows, they lay a tile over part of the aperture or cavity of the furnace.

The metal firft put in being brought to a fufion, they fill the crucible with pieces of brafs beaten in a mortar; to put them in they make ufe of a kind of iron ladle, with a long fhank at the end thereof, formed into a kind of hollow cylinder, out of which the piece is dropped.

Nothing now remains, but for the founder to take the crucible out of the fire, and carry it in a pair of iron tongs (whofe feet are bent, the better to embrace the top of the crucible) to the mould; into which he pours the melted metal, through the hole anfwering to the mafter-jet of each mould.

Thus he goes fucceffively, from one to another, till his crucible is emptied, or there is not matter enough left for another mould.

Then cafting cold water on the moulds, they take the frames out of the preffes, and the caft works out of the fand: which afterwards they work again, for another cafting. Laftly, they cut off the jets, or cafts, and fell or deliver the work to thofe who befpoke it, without any farther repairing. See BRASS and CASTING.

FOUNDERY *of ftatues, great guns, and bells.*—The art of cafting ftatues in brafs is very ancient; infomuch that its origin was too remote and obfcure even for the refearch of Pliny; an author admirably fkilled at difcovering the inventors of other arts.

All we can learn for certain is, that it was practifed, in all its perfection, firft among the Greeks; and afterwards among the Romans: and that the number of their ftatues confecrated to their gods and heroes furpaffed all belief. See STATUE.

The fingle cities of Athens, Delphos, Rhodes, &c. had each three thoufand ftatues; and Marcus Scaurus alone, though only ædile, adorned the circus with no lefs than three thoufand ftatues of brafs, for the time of the Circenfian games. This tafte for ftatues was finally carried to fuch a pitch, that it became a proverb, that in Rome the people of brafs were not lefs numerous than the Roman people.

Among us, the cafting of ftatues was but little known or practifed before the feventeenth century.

As to the *cafting of guns*, it is quite modern; and it were perhaps to be wifhed, we were as ignorant of it as the

ancients. All authors agree, that the first cannon were cast in the fourteenth century; though some affix the event to the year 1338, and others to 1380. See CANNON and GUNNERY.

The *casting of bells* is of a middle standing, between the other two. The use of bells is certainly very ancient in the western church; and the same were likewise once used in the church of the east. But, at present, F. Vansleb assures us, in his second account of Egypt, he had found but one bell in all the eastern church, and that in a monastery in the Upper Egypt. See BELL.

The matter of these large works is rarely any simple metal, but commonly a mixture of several. We shall here give the process in the foundery of each.

Method of casting statues of figures. See BRONZE.

There are three things chiefly required in casting of statues, busts, basso-relievos, vases, and other works of sculpture: *viz.* the mould, the wax, and shell, or coat. The inner mould, or core (thus called from *cœur*, as being in the heart or middle of the statue), is a rude lumpish figure, to which is given the attitudes and contours of the statue intended; it is raised on an iron grate, strong enough to sustain it; and is strengthened withinside by several bars, or ribs of iron.

It may be made at the discretion of the workmen; of potters' clay, mixed up with horse-dung and hair; or of plaster of Paris, mixed with fine brick-dust.

The use of the core in statues is to support the wax and shell, to lessen the weight, and to save metal. In bells it takes up all the inside, and preserves the space vacant where the clapper is hung. In great guns it forms the whole chace, from the mouth to the breech: and, in mortars, the chace and chamber. The iron bars and the core are taken out of the brass figure, through an aperture left in it, which is afterwards soldered up: but it is necessary to leave some of the iron bars of the core that contribute to the steadiness of the projecting parts, within the brass figure.

The wax is a representation of the intended statue. If it be a piece of sculpture, the wax must be all of the sculptor's own hand, who usually fashions it on the core itself; though it may be wrought separately in cavities, moulded, or formed, on a model, and afterwards disposed and arranged on the ribs of iron over the grate, as before, filling the vacant space in the middle with liquid plaster and brick-dust; by which means the inner mould, or core, is formed in proportion as the sculptor carries on the wax.

When the wax (which is to be of the intended thickness of the metal) is finished, they fix little waxen tubes perpendicularly to it, from top to bottom; to serve, both as jets, for the conveyance of the metal to all parts of the work: and as vent holes, to give passage to the air, which would, otherwise, occasion great disorder, when the hot metal came to encompass it. By the weight of the wax used herein, is that of the metal adjusted; ten pounds of this last being the proportion to one pound of the former. The work brought thus far, wants nothing but to be covered with its shell; which is a kind of coat, or crust, laid over the wax: and which, being of a soft matter, and even, at first, liquid, easily takes and preserves the impression of every part thereof; which it afterwards communicates to the metal, upon its taking the place of the wax, between the shell and the core. The matter of this outer mould, or shell, is varied according as different layers, or strata are applied. The first is a composition of clay, and old white crucibles, well ground and sifted, and mixed up with water, to the consistence of a colour fit for painting: accordingly, they apply it with a pencil, laying it seven or eight times over, letting it dry between the intervals. For the second impression, they add horses' dung and natural earth to the former composition. The third impression is only horses' dung and earth. Lastly, the shell is finished by laying on several more impressions of this last matter, made very thick with the hand.

The shell, thus finished, is secured and strengthened by several bands, or girts of iron, wound around it at half a foot's distance from one another, and fastened at bottom to the grate under the statue; and at the top to a circle of iron, where they all terminate.

Here it must be observed, that if the statue be so big, that it would not be easy to move the moulds, when thus provided, it must be wrought on the spot where it is to be cast.

This is performed two ways; in the first, a square hole is dug under-ground, much bigger than the mould to be made therein, and its insides lined with walls of freestone, or brick. At the bottom is made a hole, of the same materials, with a kind of furnace, having its aperture outwards: in this is a fire to be lighted, to dry the mould; and afterwards, to melt the wax. Over this furnace is placed the grate; and on this the mould, &c. framed as before explained. Lastly, at one of the edges of the square pit is made another large furnace, to melt the metal, as hereafter mentioned.

In the other way, it is sufficient to work the mould above-ground: but with the same precaution of a furnace, and grate, underneath: when finished, four walls are to be run up round it: and, by the side thereof, a massive made, for a melting furnace. For the rest, the method is the same in both. The mould being finished, and inclosed between four walls, whether under-ground, or above it, a moderate fire is lighted in the furnace under it, and the hole covered with planks, that the wax may melt gently down, and run out at pipes contrived for the purpose, at the foot of the mould; which are afterwards very exactly closed with earth, as soon as all the wax is carried off.

This done, the hole is filled up with bricks thrown in at random, and the fire in the furnace is augmented till such time as both the bricks and the mould become red-hot; which ordinarily happens in twenty-four hours. Then, the fire being extinguished, and every thing cold again, they take out the bricks, and fill up their place with earth, moistened, and a little beaten, to the top of the mould, in order to make it the more firm and steady.

Things being in this condition, there remains nothing but to melt the metal, and run it into the mould; this is the office of the furnace above, which is made in manner of an oven, with three apertures; one to put in the wood; another for a vent; and a third to run the metal out at. From this last aperture, which is kept very close whilst the metal is in fusion, a little tube or canal is laid, whereby the melted metal is conveyed into a large earthen bason over the mould; into the bottom of which all the big branches of the jets, or casts, which are to carry the metal into all the parts of the mould, are inserted.

It must be added, that these jets are all terminated, or stopped with a kind of plugs, which are kept close, that upon opening the furnace the brass, which gushes out like a torrent of fire, may not enter any of them till the bason be full enough of matter to run into them all at once; upon which occasion they pull out the plugs, which are long iron rods, with a head at one end, capable of filling the whole diameter of each tube. The hole of the furnace

is opened with a long piece of iron, fitted at the end of a pole; and the mould is then filled in an inftant. The work is now finifhed, at leaft fo much as belongs to the cafting, the reft being the fculptor's or carver's bufinefs; who, taking the figure out of the mould and earth with which it is encompaffed, faws off the jets, wherewith it appears covered over; and repairs it, with inftruments proper to his art; as chiffels, gravers, puncheons, &c.

The manner of cafting bells.—What has been hitherto fhewn of the cafting of ftatues, holds, in proportion, of the cafting of bells; that which is particular in thefe latter is as follows: firft, then, the metal is different; there being no tin in the metal of ftatues, but no lefs than a fifth part of tin in that of bells. Secondly, the dimenfions of the core, and the wax of bells, efpecially if it be a ring of feveral bells that is to be caft, are not left to chance, or the caprice of the workman; but muft be meafured, on a kind of fcale, or diapafon; which gives the height, aperture, and thicknefs, neceffary for the feveral tones required.

It need not be added, that it is on the wax that the feveral mouldings and other ornaments, and infcriptions, to be reprefented in relievo, on the outfide of the bell, are formed. The clapper, or tongue, is not properly a part of the bell, but is furnifhed from other hands. In Europe, it is ufually of iron, with a large knob at the extreme; and is fufpended in the middle of the bell. In China, it is only a huge wooden mallet, ftruck by force of arm againft the bell; whence they can have but little of that confonancy, fo much admired in fome of our rings of bells. The Chinefe have an extraordinary way of increafing the found of their bells; *viz.* by leaving a hole under the cannon; which our bell-founders would reckon a defect.

The proportions of our bells differ very much from thofe of the Chinefe. In our's, the modern proportions are, to make the diameter fifteen times the thicknefs of the brim, and the height twelve times The parts of a bell are, 1. The founding bow, terminated by an inferior circle, which grows thinner and thinner. 2. The brim or that part of a bell whereon the clapper ftrikes, and which is thicker than the reft. 3. The outward finking of the middle of the bell, or the point under which it grows wider to the brim. 4. The waift or furniture, and the part that grows wider and thicker quite to the brim. 5 The upper vafe, or that part which is above the waift. 6. The pallet which fupports the ftaple of the clapper within. 7. The bent and hollowed branches of metal uniting with the cannons, to receive the iron keys, whereby the bell is hung up to the beam which is its fupport and counterpoife, when rung out. The bufinefs of bell-foundery is reducible to three particulars. 1. The proportion of a bell. 2. The forming of the mould. And, 3. The melting of the metal. There are two kinds of proportions, *viz.* the fimple and the relative; the former are thofe proportions only that are between the feveral parts of a bell to render it fonorous; the relative proportions eftablifh a requifite harmony between feveral bells. The method of forming the profile of a bell, previoufly to its being caft, in which the proportion of the feveral parts may be feen, is as follows: the thicknefs of the brim, C 1 (fee *Plate* XV. *Mifcellan. fig.* 1.) is the foundation of every other meafure, and is divided into three equal parts. Firft, draw the line H D, which reprefents the diameter of the bell; bifect it in F and erect the perpendicular F f; let D F and H F be alfo bifected in E and G, and two other perpendiculars, E e, G a, be erected at E and G: G E will be the diameter of the top or upper vafe, *i. e.* the diameter of the top will be half that of the bell; and it will, therefore, be the diameter of the bell which will found an octave to the other. Divide the diameter of the bell or the line H D into fifteen equal parts, and one of thefe will give C 1 the thicknefs of the brim; divide again each of thefe fifteen equal parts into three other equal parts, and then form a fcale. From this fcale take twelve of the larger divifions, or $\frac{12}{15}$ of the whole fcale in the compafs, and fetting one leg in D defcribe an arc to cut the line E é in N, draw N D, and divide this line into twelve equal parts; at the point 1 erect the perpendicular 1 C = 10, and C 1 will be the thicknefs of the brim = $\frac{1}{15}$ of the diameter: draw the line C D: bifect D N and at the point of bifection 6 erect the perpendicular 6 K = $1\frac{1}{2}$ of the larger divifions on the fcale. With an opening of the compafs equal to twice the length of the fcale or thirty brims, fetting one leg in N, defcribe an arc of a circle, and with the fame leg in K and the fame opening defcribe another arc to interfect the former: on this point of interfection, as a centre, and with a radius equal to thirty brims, defcribe the arc N K; in 6 K produced take K B = $\frac{1}{3}$ of the larger meafure of the fcale or $\frac{1}{3}$ of the brim, and on the fame centre with the radius $30\frac{1}{3}$ brims defcribe an arc A B parallel to N K. For the arc B C, take twelve divifions of the fcale or twelve brims in the compafs, find a centre, and from that centre, with this opening, defcribe the arc B C, in the fame manner as N K or A B was defcribed. There are various ways of defcribing the arc K p; fome defcribe it on a centre at the diftance of nine brims from the points p and K; others, as it is done in the figure, on a centre at the diftance only of feven brims from thofe points. But it is neceffary firft to find the point p, and to determine the rounding of the bell p 1. For this purpofe, on the point C as a centre and with the radius C 1 defcribe the arc 1 p n; bifect the part 1, 2 of the line D n, and erecting the perpendicular p m, this perpendicular will cut the arc 1 p n in m, which terminates the rounding 1 p. Some founders make the bendings K a third of a brim lower than the middle of the line D N; others make the part C 1 D more acute, and inftead of making C 1 perpendicular to D N at 1, draw it $\frac{1}{6}$th of a brim higher, making it ftill equal to one brim; fo that the line 1 D is longer than the brim C 1. In order to trace out the top-part N *a*, take in the compafs eight divifions of the fcale or eight brims, and on the points N and D, as centres, defcribe arcs to interfect each other in 8; on this point 8, with a radius of eight brims, defcribe the arc N b; this arc will be the exterior curve of the top or crown; on the fame point 8, as a centre and with a radius equal to $7\frac{2}{3}$ brims, defcribe the arc A c, and this will be the interior curve of the crown, and its whole thicknefs will be one-third of the brim. As the point 8 does not fall in the axis of the bell, a centre M may be found in the axis by defcribing, with the interval of eight brims on the centres D and H, arcs which will interfect in M; and this point may be made the centre of the inner and outer curves of the crown, as before. The thicknefs of the cap which ftrengthens the crown at Q is about one-third of the thicknefs of the brim; and the hollow branches or ears about one-fixth of the diameter of the bell. The height of the bell is in proportion to its diameter as twelve to fifteen, or in the proportion of the fundamental found to its third major; whence it follows that the found of a bell is principally compofed of the found of its extremity or brim, as a fundamental, of the found of the crown which is an octave to it, and of that of the height which is a third. Encyclopedie, Art. Cloche. See Bell.

The particulars neceffary for making the mould of a bell are, 1. The earth: the moft cohefive is the beft; it muft be well ground and fifted, to prevent any chinks. 2. Brickftone; which muft be ufed for the mine, mould, or core,

and for the furnace. 3. Horſe dung, hair, and hemp, mixed with the earth, to render the cement more binding. 4. The wax for inſcriptions, coats of arms, &c. 5. The tallow equally mixed with the wax, in order to put a ſlight layer of it upon the outer mould, before any letters are applied to it. 6. The coals to dry the mould.

For making the mould, they have a ſcaffold conſiſting of four boards, ranged upon treſſels. Upon this they carry the earth, groſsly diluted, to mix it with horſe-dung, beating the whole with a large ſpatula.

The compaſſes of conſtruction are the chief inſtrument for making the mould, which conſiſt of two different legs, joined by a third piece. And laſt of all, the founders' ſhelves, on which are the engravings of the letters, cartridges, coats of arms, &c.

They firſt dig a hole, of a ſufficient depth to contain the mould of the bell, together with the caſe, or cannon, under ground; and about ſix inches lower than the terre-plein, where the work is performed. The hole muſt be wide enough for a free paſſage between the mould and walls of the hole; or between one mould and another, when ſeveral bells are to be caſt. At the centre of the hole is a ſtake erected, that is ſtrongly faſtened in the ground. This ſupports an iron-peg, on which the pivot of the ſecond branch of the compaſſes turns. The ſtake is encompaſſed with a ſolid brick-work, perfectly round, about half a foot high, and of the propoſed bell's diameter. This they call a millſtone. The parts of the mould are the core, the model of the bell, and the ſhell. When the outer ſurface of the core is formed, they begin to raiſe the core, which is made of bricks that are laid in courſes of equal height upon a layer of plain earth. At the laying of each brick, they bring near it the branch of the compaſſes, on which the curve of the core is ſhaped, ſo as that there may remain between it and the curve the diſtance of a line, to be afterwards filled up with layers of cement. The work is continued to the top, only leaving an opening for the coals to bake the core. This work is covered with a layer of cement made of earth and horſe-dung, on which they move the compaſſes of conſtruction, to make it of an even ſmoothneſs every where.

The firſt layer being finiſhed, they put the fire to the core, by filling it half with coals, through an opening that is kept ſhut, during the baking, with a cake of earth, that has been ſeparately baked. The firſt fire conſumes the ſtake, and the fire is left in the core half, or, ſometimes, a whole day: the firſt layer being thoroughly dry, they cover it with a ſecond, third, and fourth; each being ſmoothed by the board of the compaſſes, and thoroughly dried before they proceed to another.

The core being completed, they take the compaſſes to pieces, with intent to cut off the thickneſs of the model, and the compaſſes are immediately put in their place, to begin a ſecond piece of the mould. It conſiſts of a mixture of earth and hair, applied with the hand on the core, in ſeveral cakes that cloſe together. This work is finiſhed by ſeveral layers of a thinner cement of the ſame matter, ſmoothed by the compaſſes, and thoroughly dried, before another is laid on. The laſt layer of the model is a mixture of wax and greaſe ſpread over the whole. After which are applied the inſcriptions, coats of arms, &c. beſmeared with a pencil dipped in a veſſel of wax on a chaffing-diſh: this is done for every letter. Before the ſhell is begun, the compaſſes are taken to pieces, to cut off all the wood that fills the place of the thickneſs to be given to the ſhell.

The firſt layer is the ſame earth with the reſt, ſifted very fine; whilſt it is tempering in water, it is mixed with cow's hair, to make it cohere. The whole being a thin cullis, is gently poured on the model, that ſinks exactly all the ſinuoſities of the figures, &c. and this is repeated till the whole is two lines thick over the model. When this layer is thoroughly dried, they cover it with a ſecond of the ſame matter, but ſomething thicker: when this ſecond layer becomes of ſome conſiſtence, they apply the compaſſes again, and light a fire in the core, ſo as to melt off the wax of the inſcriptions, &c.

After this, they go on with other layers of the ſhell, by means of the compaſſes. Here they add to the cow's hair a quantity of hemp, ſpread upon the layers, and afterwards ſmoothed by the board of the compaſſes. The thickneſs of the ſhell comes to four or five inches lower than the millſtone before obſerved, and ſurrounds it quite cloſe, which prevents the extravaſation of the metal. The wax ſhould be taken out before the melting of the metal.

The ear of the bell requires a ſeparate work, which is done during the drying of the ſeveral incruſtations of the cement. It has ſeven rings, the ſeventh is called the bridge, and unites the others, being a perpendicular ſupport to ſtrengthen the curves. It has an aperture at the top, to admit a large iron peg, bent at the bottom; and this is introduced into two holes in the beam, faſtened with two ſtrong iron keys. There are models made of the rings, with maſſes of beaten earth, that are dried in the fire, in order to have the hollow of them. Theſe rings are gently preſſed upon a layer of earth and cow's hair one-half of its depth; and then taken out without breaking the mould. This operation is repeated twelve times for twelve half-moulds, that two and two united may make the hollows of the ſix rings: the ſame they do for the hollow of the bridge, and bake them all, to unite them together.

Upon the open place left for the coals to be put in, are placed the rings that conſtitute the ear. They firſt put into this open place the iron ring to ſupport the clapper of the bell; then they make a round cake of clay, to fill up the diameter of the thickneſs of the core. This cake, after baking, is clapped upon the opening, and ſoldered with a thin mortar ſpread over it, which binds the cover cloſe to the core.

The hollow of the model is filled with an earth, ſufficiently moiſt, to fix on the place, which is ſtrewed, at ſeveral times, upon the cover of the core; and they beat it gently with a peſtle to a proper height; and a workman ſmooths the earth at top with a wooden trowel dipped in water.

Upon this cover, to be taken off afterwards, they aſſemble the hollows of the rings. When every thing is in its proper place, they ſtrengthen the outſide of the hollows with mortar, in order to bind them with the bridge, and keep them ſteady at the bottom, by means of a cake of the ſame mortar which fills up the whole aperture of the ſhell. This they let dry, that it may be removed without breaking. To make room for the metal they pull off the hollows of the rings, through which the metal is to paſs, before it enters into the vacuity of the mould. The ſhell being unloaded of its ear, they range under the millſtone five or ſix pieces of wood, about two feet long, and thick enough to reach almoſt the lower part of the ſhell; between theſe and the mould they drive in wooden wedges with a mallet, to ſhake the ſhell of the model whereon it reſts, ſo as to be pulled up, and got out of the pit.

When this and the wax are removed, they break the model and layer of earth, through which the metal muſt run, from the hollow of the rings, between the bell and the core.

They smoke the inside of the shell, by burning straw under it, that helps to smooth the surface of the bell. Then they put the shell in the place, so as to leave the same interval between that and the core; and before the hollows of the rings or the cap are put on again, they add two vents, that are united to the rings, and to each other, by a mass of baked cement. After which they put on this mass of the cap, the rings, and vents, over the shell, and solder it with thin cement, which is dried gradually by covering it with burning coals. Then they fill up the pit with earth, beating it strongly all the time, round the mould.

The furnace has a place for the fire, and another for the metal. The fire-place has a large chimney, with a spacious ash-hole: the furnace which contains the metal is vaulted, whose bottom is made of earth, rammed down; the rest is built with brick. It has four apertures; the first, through which the flame reverberates; the second is closed with a stopple, that is opened for the metal to run; the others are to separate the dross, or scoriæ, of the metal by wooden rakes; through these last apertures passes the thick smoke. The ground of the furnace is built sloping, for the metal to run down. See Dict. Commerc. Eng. edit. art. Foundery.

Foundery. *Manner of casting great guns, or pieces of artillery.*—The casting of cannons, mortars, and other pieces of artillery, is performed much like that of statues and bells; especially as to what regards the wax, shell, and furnaces.

All pieces of artillery are now cast solid, and bored afterwards, by means of a machine invented at Strasburgh, (see *Boring of* Cannon,) and much improved by Mr. Verbruggen, head founder at Woolwich. The gun to be bored was at first placed in a perpendicular position; but the machines used for this purpose have lately been made to bore horizontally, and much more exactly than those that bore in a vertical situation. Whilst the inside is bored, the outside is turned and polished at the same time.

As to the metal, it is somewhat different from both; as having a mixture of tin, which is not in that of statues; and only having half the quantity of tin that is in bells, *i. e.* at the rate of ten pound of tin to an hundred of copper. The respective quantities of different metals that should enter into the composition for brass cannon is not absolutely decided; the most common proportions of the ingredients are the following: *viz.* to 240lb. of metal fit for casting, they put 68lb. of copper, 25lb. of brass, and 12lb. of tin. To 4200lb. of metal fit for casting, the Germans put 368$\frac{73}{41}$lb. of copper, 201$\frac{13}{41}$lb. of brass, and 307$\frac{30}{41}$lb. of tin. Others, again, use 100lb. of copper, 6lb. of brass, and 9lb. of tin; and lastly, others make use of 100lb. of copper, 10lb. of brass, and 15lb. of tin. See Cannon.

A cannon is always shaped a little conical, being thickest of metal at the breech, where the greatest effort of the gunpowder is made, and diminishing thence to the muzzle; so that if the mouth be two inches thick of metal, the breech is six. See Cannon.

Its length is measured in calibers, *i. e.* in diameters of the muzzle. Six inches at the muzzle require twenty calibers, or ten feet in length; there is always about the sixth of an inch allowed play for the ball. For the parts, and their respective proportions of different sorts of guns, see Cannon and Gun. The method of casting iron cannon differs very little from that of brass.

Foundery, *Letter, or the method of casting printing Letters.*—The invention of printing letters we shall speak of under Printing and Letter.

Their difference, kind, &c. have already been explained under the articles Character, &c.

In the business of cutting, casting, &c. letters for printing, the letter-cutter must be provided with a vice, hand-vice, hammers and files of all sorts for watch-makers' use; as also gravers and sculpters of all sorts, and an oil-stone, &c. suitable and sizeable to the several letters to be cut: a flat gauge made of box to hold a rod of steel, or the body of a mould, &c. exactly perpendicular to the flat of the using-file: a sliding gauge, whose use is to measure and set off distances between the shoulder and the tooth, and to mark it off from the end, or from the edge of the work; a face-gauge, which is a square notch cut with a file into the edge of a thin plate of steel, iron, or brass, of the thickness of a piece of common tin, whose use is to proportion the face of each sort of letter, *viz.* long letters, ascending letters, and short letters. So there must be three gauges, and the gauge for the long letters is the length of the whole body supposed to be divided into forty-two equal parts. The gauge for the ascending letters, Roman and Italic, are $\frac{5}{7}$, or 30 parts of 42, and 33 parts for the English face. The gauge for the short letters is $\frac{3}{7}$ or 18 parts of 42 of the whole body for the Roman and Italic, and 22 parts for the English face.

The Italic and other standing gauges are to measure the scope of the Italic stems, by applying the top and bottom of the gauge to the top and bottom lines of the letters, and the other side of the gauge to the stem; for when the letter complies with these three sides of the gauge, that letter has its true shape.

The next care of the letter-cutter is to prepare good steel punches, well-tempered, and quite free from all veins of iron; on the face of which he draws or marks the exact shape of the letter, with pen and ink, if the letter be large; or with a smooth blunted point of a needle, if it be small; and then with sizeable and proper shaped and pointed gravers and sculpters, digs or sculps out the steel between the strokes or marks he made on the face of the punch, and leaves the marks standing on the face. Having well shaped the inside strokes of his letter, he deepens the hollows with the same tools: for if a letter be not deep in proportion to its width, it will, when used at press, print black, and be good for nothing. This work is generally regulated by the depth of the counter-punch. Then he works the outside with proper files till it be fit for the matrice.

But before we proceed to the sinking and justifying of the matrices, we must provide a mould to justify them by, of which you have a draught in *Plate* XV. *Miscellany*, *figs.* 2, 3.

Every mould is composed of an upper and an under part. The under part is delineated in *fig.* 2. The upper part is marked *fig.* 3, and is in all respects made like the under part, excepting the stool behind, and the bow, or spring, also behind; and excepting a small roundish wire between the body and carriage, near the break where the under part hath a small rounding groove made in the body. This wire, or rather half-wire, in the upper part, makes the nick in the shank of the letter, when part of it is received into the groove in the under part. These two parts are so exactly fitted and gauged into one another (*viz.* the male gauge, marked c in *fig.* 3. into the female marked g in *fig.* 2.) that when the upper part of the mould is properly placed on, and in the under part of the mould, both together, make the entire mould, and may be slid backwards for use so far, till the edge of either of the bodies on the middle of either carriage comes just to the edge of the female gauges, cut in each carriage: and they may be slid for-

wards ſo far, till the bodies on either carriage touch each other: and the ſliding of theſe two parts of the mould backwards makes the ſhank of the letter thicker, becauſe the bodies in each part ſtand wider aſunder, and the ſliding them forwards makes the ſhank of the letter thinner, becauſe the bodies on each part of the mould ſtand cloſer together.

The parts of the mould are as follow: viz.

a The carriage.
b The body.
c The male gauge.
d e The mouth-piece.
f i The regiſter.
g The female gauge.
h The hag.
a a a a The bottom plate.
b b b The wood, on which the bottom plate lies.
c c c The mouth.
d d The throat.
e d d The pallet.
f The nick.
g g The ſtool.
h h The ſpring or bow.

Then the mould muſt be juſtified: and firſt the founder juſtifies the body, by caſting about twenty proofs or ſamples of letters, which are ſet in a compoſing ſtick, with all their nicks towards the right hand; and then by comparing theſe with the pattern letters, ſet up in the ſame manner, he finds the exact meaſure of the body to be caſt. He alſo tries if the two ſides of the body are parallel, or that the body be no bigger at the head than at the foot; by taking half the number of his proofs, and turning them with their heads to the feet of the other half; and if then the heads and the feet be found exactly even upon each other, and neither to drive out nor get in, the two ſides may be pronounced parallel. He farther tries whether the two ſides of the thickneſs of the letter be parallel by firſt ſetting his proofs in the compoſing ſtick with their nicks upwards; and then turning one-half with their heads to the feet of the other half: and if the heads and feet lie exactly upon each other, and neither drive out nor get in, the two ſides of the thickneſs are parallel.

The mould thus juſtified: the next buſineſs is to prepare the matrices. A matrice is a piece of braſs or copper of about an inch and a half long, and of a thickneſs in proportion to the ſize of the letter it is to contain. In this metal is ſunk the face of the letter intended to be caſt, by ſtriking the letter punch about the depth of an n. After this the ſides and face of the matrice muſt be juſtified and cleared, with files, of all bunchings made by ſinking the punch.

Every thing thus prepared, it is brought to the furnace, which is built of brick upright, with four ſquare ſides, and a ſtone on the top, in which ſtone is a wide round hole for the pan to ſtand in. A foundery of any conſequence has ſeveral of theſe furnaces in it.

As to the metal of which the types are to be caſt, this, in extenſive founderies, is always prepared in large quantities; but caſt into ſmall bars of about twenty pounds weight to be delivered out to the workmen as occaſion requires. In the letter foundery which has been long carried on with reputation, under the direction of Dr. Alexander Wilſon, and ſons, at Glaſgow, we are informed, that a ſtock of metal is made up at two different times of the year, ſufficient to ſerve the caſters at the furnace for ſix months each time. For this purpoſe a large furnace is built under a ſhade, furniſhed with a wheel vent, in order the more equally to heat the ſides of a ſtrong pot of caſt iron, which holds, when full, fifteen hundred weight of the metal. The fire being kindled below, the bars of lead are let ſoftly down into the pot, and their fuſion promoted by throwing in ſome pitch and tallow, which ſoon inflame. An outer chimney, which is built ſo as to project about a foot over the fartheſt lip of the pot, catches hold of the flame by a ſtrong draught, and makes it act very powerfully in melting lead; whilſt it ſerves at the ſame time to convey away all the fumes, &c. from the workmen, to whom this laborious part of the buſineſs is committed. When the lead is thoroughly melted, a due proportion of the regulus of antimony and other ingredients are put in, and ſome more tallow is inflamed, to make the whole incorporate ſooner. The workmen now having mixed the contents of the pot very thoroughly, by ſtirring it long with a large iron ladle, next proceed to draw the metal off into the ſmall troughs of caſt iron which are ranged, to the number of fourſcore, upon a level platform, faced with ſtone, built towards the right hand. In the courſe of a day fifteen hundred weight of metal can be eaſily prepared in this manner; and the operation is continued for as many days as are neceſſary to prepare a ſtock of metal, of all the various degrees of hardneſs. After this the whole is diſpoſed into preſſes, according to its quality, to be delivered out occaſionally to the workmen.

The founder muſt be now provided with a ladle, which differs nothing from other iron ladles, but in its ſize. And he is provided always with ladles of ſeveral ſizes, which he uſes according to the ſize of the letter he is to caſt. Before the caſter begins to caſt, he muſt kindle his fire in the furnace to melt the metal in the pan. Therefore he takes the pan out of the hole in the ſtone, and there lays in coals and kindles them; and, when they are well kindled, he ſets the pan in again and puts in metal into it to melt; if it be a ſmall bodied letter he caſts, or a thin letter of great bodies, his metal muſt be very hot; nay ſometimes red-hot, to make the letter come. Then having choſen a ladle that will hold about ſo much as the letter and break is, he lays it at the ſtoking hole, where the flame burſts out, to heat. Then he ties a thin leather, cut with its narrow end againſt the face to the leather groove of the matrice, by whipping a brown thread twice about the leather-groove, and faſtening the thread with a knot. Then he puts both halves of the mould together, and puts the matrice into the matrice-cheek, and places the foot of the matrice on the ſtool of the mould, and the broad end of the leather upon the wood of the upper half of the mould, but not tight up, leſt it might hinder the foot of the matrice from ſinking cloſe down upon the ſtool in a train of work. Then laying a little roſin on the upper-wood of the mould, and having his caſting-ladle hot, he with the bolling ſide of it melts the roſin: and, when it is yet melted, preſſes the broad end of the leather hard down on the wood, and ſo faſtens it to the wood: all this is the preparation.

Now he comes to caſting. Wherefore placing the under half of the mould in his left hand with the hook or hag forward, he clutches the ends of its wood between the lower part of the ball of his thumb and his three hind fingers; then he lays the upper half of the mould upon the under half, ſo that the male gauges may fall into the female gauges, and at the ſame time the foot of the matrice places itſelf upon the ſtool; and, claſping his left

nand thumb ſtrong over the upper half of the mould he nimbly catches hold of the bow or ſpring with his right hand fingers at the top of it, and his thumb under it, and places the point of it againſt the middle of the notch in the backſide of the matrice, preſſing it as well forwards towards the mould, as downwards, by the ſhoulder, of the notch cloſe upon the ſtool, while at the ſame time with his hinder fingers, as aforeſaid, he draws the under half of the mould towards the ball of his thumb, and thruſts by the ball of his thumb the upper part towards his fingers, that both the regiſters of the mould may preſs againſt both ſides of the matrice, and his thumb and fingers preſs both halves of the mould cloſe together.

Then he takes the handle of his ladle in his right hand, and with the boll of it gives a ſtroke, two or three, outwards upon the ſurface of the melted metal, to ſcum or clear it from the film or duſt that may ſwim upon it; then takes up the ladle full of metal, and having his mould, as aforeſaid, in his left hand, he a little twiſts the left ſide of his body from the furnace, and brings the geat of his ladle (full of metal) to the mouth of the mould, and twiſts the upper part of his right hand towards him to turn the metal into it, while at the ſame moment of time he jilts the mould in his left hand forwards, to receive the metal with a ſtrong ſhake (as it is called); not only into the bodies of the mould, but while the metal is yet hot running, ſwiftly and ſtrongly, into the very face of the matrice, to receive its perfect form there, as well as in the ſhank.

Then he takes the upper half of the mould off the under half, by placing his right hand thumb on the end of the wood next his left hand thumb, and his two middle-fingers at the other end of the wood; and finding the letter and break lie in the under half of the mould, (as moſt commonly by reaſon of its weight it does,) he throws or toſſes the letter, break and all, upon a ſheet of waſte paper laid for that purpoſe on the bench, juſt a little beyond his left hand, and is then ready to caſt another letter as before; and alſo, the whole number that is to be caſt with that matrice.

A workman will ordinarily caſt about three thouſand of theſe letters in a day.

When the caſters at the furnace have got a ſufficient number of types upon the tables, a ſet of boys come, and nimbly break away the jets from them: the jets are thrown into the pots, and the types are carried away in parcels to other boys, who paſs them ſwiftly under their fingers, defended by leather, upon ſmooth flat ſtones, in order to poliſh their broad-ſides This is a very dextrous operation, and is a remarkable inſtance of what may be effected by the power of habit and long practice; for theſe boys, in turning up the other ſide of the type, do it ſo quickly by a mere touch of the fingers of the left hand, as not to require the leaſt perceptible intermiſſion in the motion of the right hand upon the ſtone. The types, thus finely ſmoothed and flattened on the broad-ſides, are next carried to another ſet of boys, who ſit at a ſquare table, two on each ſide, and there are ranged up on long rulers, or ſticks, fitted with a ſmall projection, to hinder them from ſliding off backwards. When theſe ſticks are ſo filled, they are placed, two and two, upon a ſet of wooden pins fixed into the wall, near the dreſſer, ſometimes to the amount of a hundred, in order to undergo the finiſhing operations. This workman, who is always the moſt expert and ſkilful in all the different branches carried on at the foundery, begins by taking one of theſe ſticks, and, with a peculiar addreſs, ſlides the whole column of types off upon the dreſſing-ſtick: this is made of well-ſeaſoned mahogany, and furniſhed with two end-pieces of ſteel, a little lower than the body of the types, one of which is moveable, ſo as to approach the other by means of a long ſcrew-pin, inſerted in the end of the ſtick. The types are put into this ſtick with their faces next to the back or projection; and after they are adjuſted to one another ſo as to ſtand even when they are bound up, by ſcrewing home the moveable end piece. It is here where the great and requiſite accuracy of the moulds comes to be perceived; for in this caſe the whole column, ſo bound up, lies flat and true upon the ſtick, the two extreme types being quite parallel, and the whole has the appearance of one ſolid continuous plate of metal. The leaſt inaccuracy in the exact paralleliſm of the individual type, when multiplied ſo many times, would render it impoſſible to bind them up in this manner, by diſpoſing them to riſe or ſpring from the ſtick by the ſmalleſt preſſure from the ſcrew. Now, when lying ſo conveniently with the narrow edges uppermoſt, which cannot poſſibly be ſmoothed in the manner before mentioned by the ſtones, the workman does this more effectually by ſcraping the ſurface of the column with a thick-edged but ſharp razor, which at every ſtroke brings on a very fine ſmooth ſkin, like to poliſhed ſilver; and thus he proceeds till in about half a minute he comes to the farther end of the ſtick. The other edges of the types are next turned upwards, and poliſhed in the ſame manner. It is whilſt the types thus lie in the dreſſing-ſtick that the operation of bearding or barbing is performed, which is effected by running a plane, faced with ſteel, along the ſhoulder of the body next to the face, which takes more or leſs off the corner, as occaſion may require. Whilſt in the dreſſing-ſtick they are alſo grooved, which is a very material operation. In order to underſtand this, it muſt be remembered, that when the types are firſt broken off from the jets, ſome ſuperfluous metal always remains, which would make them bear very unequally againſt the paper whilſt under the printing-preſs, and effectually mar the impreſſion. That all theſe inequalities may, therefore, be taken away, and that the bearings of every type may be regulated by the ſhoulders imparted to them all alike from the mould, the workman or dreſſer proceeds in the following manner. The types being ſcrewed up in the ſtick, as before mentioned, with the jet-end outermoſt, and projecting beyond the wood about one eighth of an inch, the ſtick is put into an open preſs, ſo as to preſent the jet-end uppermoſt, and then every thing is made faſt by driving a long wedge, which bears upon a ſlip of wood, which lies cloſe to the types the whole length: then a plough or plane is applied, which is ſo conſtructed as to embrace the projecting part of the types betwixt its long ſides, which are made of poliſhed iron. When the plane is thus applied, the ſteel cutter bearing upon that part between the ſhoulders of the types, where the inequalities lie, the dreſſer dextrouſly glides it along, and by this means ſtrips off every irregular part that comes in the way, and ſo makes an uniform groove the whole length, and leaves the two ſhoulders ſtanding; by which means every type becomes preciſely like to another, as to the height againſt paper. The types being now finiſhed, the ſtick is taken out of the preſs, and the whole column replaced upon the other ſtick; and after the whole are ſo dreſſed, he proceeds to pick out the bad letters, previouſly to putting them up into pages and papers. In doing this he takes the ſtick into his left hand, and turning the faces near to the light, he examines them carefully, and whenever an imperfect or damaged letter occurs, he nimbly plucks it out with a ſharp bodkin, which he holds in the right hand for that purpoſe. Thoſe letters which, from their form, project over the body

of the type, and which cannot on this account be rubbed on the ftones, are fcraped on the broad-fides with a knife or file, and fome of the metal next the face pared away with a pen-knife, in order to allow the type to come clofe to any other. This operation is called kerning.

The excellence of printing types confifts not only in the due performance of all the operations above defcribed, but alfo in the hardnefs of the metal, form, and fine proportion of the character, and in the exact bearing and ranging of the letters in relation to one another.

Foundery, *Military*. Under the feveral appropriate heads, we have furnifhed information regarding the feveral kinds of foundery neceffary to the eftablifhment of that variety of profeffions, wherein caftings of different kinds, whether in metal, wax, plafter, &c. are defiderata: we now have to offer a few remarks on fuch as appertain more particularly to the fupply of our arfenals.

The calling of cannon, fhot, &c. was, until about half a century ago, confidered an arduous undertaking; and fo little were the fundamental principles of the art underftood, that we are affured not one in three of the fhells caft for the mortar fervice could be admitted into the ftores. Such have been the improvements made, that thoufands of articles, which ufed to be from neceffity made of wrought iron, are now to be had from the founderies at lefs than one-fifth of their former prices; while the material itfelf has been fo highly perfected, that inftances have been known of caft-iron being fufficiently foft to bear the file, and fufficiently ductile to undergo the hammer. Such, indeed, could not be done but at confiderable expence; nor does it appear that much good could refult in general. With refpect to military apparatus, it is found expedient to have the whole of our cannon, mortars, carronades, fhot, fhells, and garrifon gun-carriages, caft at the feveral founderies eftablifhed in the vicinity of coal and iron mines; whereby the work is done at comparatively a low expence, and the articles can be conveyed by water to the warren at Woolwich much under the prices at which they could be caft at the place, to which both the iron and the coals muft be tranfported.

The French have, fince the commencement of the revolution, fhewn what may be effected in this branch of military economy, by a people determined to overcome every difficulty, and to apply their refources, whether public or private, towards national purpofes. It is a well afcertained fact, that in feveral of the departments of France, from which the trains of artillery, together with the feveral ftores appertaining to them, had been withdra n, the people fupplied their national guards with field-piec caft in fmall temporary founderies, where the furnaces we rarely equal to heating more than from twenty to thirty unds of bell-metal, &c. of which the facred edifices, & throughout the country had been ftripped. By a due ombination of the whole, very ferviceable cannon, and efpeci ly howitzers, which feem to be a favourite fpecies of artill y among the French, were thus fupplied.

Though it muft be admitted that a foun ery fuited to cafting cannon, of any defcription, could n be attached to the ordnance department of armies ferving out of the kingdom, we are inclined to hazard the opin n, that fmall laboratory furnaces, adequate to the caftin of fhot and grape, but efpecially of mufket balls, migl be annexed thereto. In fome inftances, when the ftock f grape-fhot has been expended, it has become neceffary o make cafe-fhot of mufket balls, whereby the infantry h ve been very ill fupplied with ammunition. If, in fuch inft nces, portable furnaces, and crucibles, together with prope moulds. have been at hand, (for the whole might be conv yed in a waggon, or perhaps in a cart,) abundance of re afe iron could have been formed into grape-fhot; and the ould have been no fcarcity of mufket ammunition.

Nor can we fee any objection to the fi ly of proper materials for eftablifhing founderies, fuited t cafting field-pieces, being fhipped with extenfive armame ts proceeding on foreign fervice; fince the fpace they wo ccupy muft be far lefs than is required for that immenfe quantity of ftores neceffarily fent to places where no foundery exifts. Hence tonnage, time, and treafure, are often lavifhly expended. The cafting of fhot and fhells, in fuch fituations, would generally prove eafy, and liberate many a tranfport from the conveyance of fuch dead-weight, as not only precludes the fupply of other equally neceffary ftores, but, in many inftances, rifks, or even caufes, a total lofs.

Fuel

FUEL, in *Philosophy*, the pabulum of fire, or whatever receives and retains fire, and is consumed, or rendered insensible thereby.

A great deal of nicety is required in choosing the proper fuel to raise and continue the several degrees of fire in chemical operations. Dr. Black divides fuels into five

claſſes; the firſt comprehends the fluid inflammable bodies; the ſecond, peat or turf; the third, charcoal of wood; the fourth, pit-coal charred; and the fifth, wood, or pit-coal, in a crude ſtate, and capable of yielding a copious and bright flame.

The fluid inflammables are conſidered as diſtinct from the ſolid, on this account, that they are capable of burning upon a wick, and become in this way the moſt manageable ſources of heat; though, on account of their price, they are never employed for producing it in great quantities; and are only uſed when a gentle degree, or a ſmall quantity of heat is ſufficient. The ſpecies which belong to this claſs are alcohol and different oils.

The firſt of theſe, alcohol, when pure and free of water, is as convenient and manageable a fuel for producing moderate or gentle heats as can be deſired. Its flame is perfectly clean, and free from any kind of ſoot; it can eaſily be made to burn ſlower or faſter, and to produce leſs or more heat, by changing the ſize or number of the wicks upon which it burns; for as long as theſe are fed with ſpirit, in a proper manner, they continue to yield flame of preciſely the ſame ſtrength. The cotton, or other materials, of which the wick is compoſed, is not ſcorched or conſumed in the leaſt, becauſe the ſpirit with which it is conſtantly ſoaked is incapable of becoming hotter than 174°, Fahrenheit, which is conſiderably below the heat of boiling water. It is only the vapour that ariſes from it which is hotter, and this too only in its outer parts, that are moſt remote from the wick, and where only the combuſtion is going on, in conſequence of communication and contact with the air. At the ſame time, as the alcohol is totally volatile, it does not leave any fixed matter which, by being accumulated on the wick, might render it foul and fill up its pores. The wick, therefore, continues to imbibe the ſpirit as freely, after ſome time, as it did at the firſt. Theſe are the qualities of alcohol as a fuel. But theſe qualities belong only to a ſpirit that is very pure. If, on the contrary, it be weak, and contain water, the water, being leſs volatile, does not evaporate ſo faſt from the wick as the more ſpirituous part; and the wick becomes, after ſome time, ſo much ſoaked with water that it does not imbibe the ſpirit properly. The flame becomes much weaker, or is altogether extinguiſhed. When alcohol is uſed as a fuel, therefore, it ought to be made as ſtrong, or free from water, as poſſible.

Oil, although fluid like ſpirit of wine, and capable of burning in a ſimilar manner, is not ſo convenient in many reſpects. It is diſpoſed to emit ſoot; and this applying itſelf to the bottom of the veſſel expoſed to it, and, increaſing in thickneſs, forms, by degrees, a ſoft and ſpongy medium, through which heat is not ſo freely and quickly tranſmitted. This was obſerved by Muſchenbroeck in his experiments upon the expanſions of metalline rods heated by lamps. It is true we can prevent this entirely, by uſing very ſmall wicks, and increaſing the number, if neceſſary, to produce the heat required. Or, we may employ one of thoſe lamps, in which a ſtream of air is allowed to riſe through the middle of the flame, or to paſs over its ſurface with ſuch velocity as to produce a more complete inflammation than ordinary. But we ſhall be as much embarraſſed in another way, for the oils commonly uſed, being capable of aſſuming a heat greatly above that of boiling water, ſcorch and burn the wick, and change its texture, ſo that it does not imbibe the oil ſo faſt as before. Some have attempted a remedy, by making the wick of incombuſtible materials, as aſbeſtos, or wire; but ſtill, as the oil does not totally evaporate, but leaves a ſmall quantity of groſs fixed carbonaceous matter, this, conſtantly accumulating, clogs the wick to ſuch a degree, that the oil cannot aſcend, the flames become weaker, and, in ſome caſes, are entirely extinguiſhed. There is, however, a difference among the different oils in this reſpect; ſome being more totally volatile than others. But the beſt are troubleſome in this way, and the only remedy is to change the wicks often, though we can hardly do this and be ſure of keeping always an equal flame.

The ſecond kind of fuel mentioned, peat, is ſo ſpongy that, compared with the more ſolid fuels, it is unfit to be employed for producing very ſtrong heats. It is too bulky for this: we cannot put into a furnace, at a time, a quantity that correſponds with the quick conſumption that muſt neceſſarily go on when the heat is violent. There is, no doubt, a great difference in this reſpect among different kinds of this fuel; but this is the general character of it. However, when we deſire to produce and keep up, by means of cheap fuel, an extremely mild gentle heat, we can hardly uſe any thing better than peat. But it is beſt to have it previouſly charred, that is, ſcorched, or burnt to black coal. When prepared for uſe in that manner, it is capable of being made to burn more ſlowly and gently, or will bear, without being extinguiſhed altogether, a greater diminution of the quantity of air, with which it is ſupplied, than any other of the ſolid fuels. Dr. Boerhaave found it extremely convenient and manageable in his Furnus Studiorum.

The next fuel, in order, is the charcoal of wood. This is prepared by piling up billets of wood into a pyramidal heap, with ſeveral ſpiracles, or flues, formed through the pile. Chips and bruſhwood are put into thoſe below, and the whole is ſo conſtructed that, when kindled, it kindles almoſt over the whole pile in a very ſhort time. It would burſt out into a blaze, and be quickly conſumed to aſhes, were it not covered all over with earth, or clay, beaten cloſe, leaving openings at all the ſpiracles. Theſe are carefully watched; and, whenever the white watery ſmoke is obſerved to be ſucceeded by thin blue, and tranſparent ſmoke, the whole is immediately ſtopped; this being the indication of all the watery vapour being gone, and the burning of the true coaly matter commencing. Thus is a pretty ſtrong red heat raiſed through the whole maſs, and all the volatile matters are diſſipated by it, and nothing now remains but the charcoal. The holes being all ſtopped in ſucceſſion, as this change of the ſmoke is obſerved, the fire goes out for want of air. The pile is now allowed to cool. This requires many days; for, charcoal being a very bad conductor of heat, the pile long remains red hot in the centre, and, if opened in this ſtate, would inſtantly burn with fury.

Small quantities may be procured at any time, by burning wood in cloſe veſſels. Little pieces may be very finely prepared, at any time, by plunging the wood in lead melted and red hot.

This is the chief fuel uſed by the chemiſts abroad, and has many good properties. It kindles quickly, emits few watery or other vapours while burning, and when conſumed leaves few aſhes, and thoſe very light. They are, therefore, eaſily blown away, ſo that the fire continues open, or pervious to the current of air which muſt paſs through it to keep it burning. This ſort of fuel, too, is capable of producing as intenſe a heat as can be obtained by any; but in thoſe violent heats it is quickly conſumed, and needs to be frequently ſupplied.

Foſſil coals charred, called cinders, or cokes, have, in many reſpects, the ſame properties as charcoal of wood; as kindling more readily in furnaces than when they are not charred, and not emitting watery, or other groſs ſmoke,

while they burn. This ſort of charcoal is even greatly ſuperior to the other in ſome properties.

It is a much ſtronger fuel, or contains the combuſtible matter in greater quantity, or in a more condenſed ſtate. It is, therefore, conſumed much more ſlowly on all occaſions, and particularly when employed for producing intenſe melting heats. The only inconveniences that attend it are, that, as it conſumes, it leaves much more aſhes than the other, and theſe much heavier too, which are, therefore, liable to collect in ſuch quantity as to obſtruct the free paſſage of air through the fire; and further, that when the heat is very intenſe theſe aſhes are diſpoſed to melt or vitrify into a tenacious droſſy ſubſtance, which clogs the grate, the ſides of the furnace and the veſſels. This laſt inconvenience is only troubleſome, however, when the heat required is very intenſe. In ordinary heat the aſhes do not melt, and though they are more copious and heavy than thoſe of charcoal of wood, they ſeldom choke up the fire conſiderably, unleſs the bars of the grate be too cloſe together.

This fuel, therefore, is preferable, in moſt caſes, to the charcoal of wood, on account of its burning much longer, or giving much more heat before it is conſumed. The heat produced, by equal quantities, by weight, of pit-coal, wood-charcoal and wood itſelf, are nearly in proportion of 5, 4, and 3. The reaſon why both theſe kinds of charcoal are preferred, on moſt occaſions, in experimental chemiſtry, to the crude wood, or foſſil coal from which they are produced, is, that the crude fuels are deprived, by charring, of a conſiderable quantity of water, and ſome other volatile principles, which are evaporated during the proceſs of charring, in the form of ſooty ſmoke or flame. Theſe volatile parts, while they remain in the fuel, make it unfit (or leſs fit) for many purpoſes in chemiſtry. For beſides obſtructing the vents with ſooty matter, they require much heat to evaporate them; and, therefore, the heat of the furnace, in which they are burnt, is much diminiſhed and waſted by every addition of freſh fuel, until the freſh fuel is completely inflamed, and reſtores the heat to its former ſtrength.

But theſe great and ſudden variations of the heat of a furnace are quite inconvenient in moſt chemical proceſſes. In the greater number of chemical operations, therefore, it is much more convenient to uſe charred fuel, than the ſame fuel in its natural ſtate.

There are, at the ſame time, ſome kinds of foſſil coal, which are exceptions to what has now been delivered in general. We meet with ſome of them that leave a ſmaller proportion of aſhes than others, and the aſhes of ſome are not ſo liable to melt in violent heats. There is one ſpecies too, ſuch as the Kilkenny coal of Ireland, and which occurs likewiſe in ſome parts of this country, that does not contain any ſenſible quantity of water, or other ſuch volatile principles. But this may be called a ſort of native charcoal. It has the appearance of ordinary coal, but, when thrown into the fire, does not emit ſmoke or ſoot. It merely becomes red, gives a ſubtile blue flame, and conſumes like charcoal; only it laſts ſurprizingly long, or continues to give heat for a very long time before it is totally conſumed. But it cannot be made to burn ſo as to produce a gentle heat If not in conſiderable quantity, and violently heated, it is ſoon extinguiſhed.

In uſing this kind of fuel, it is proper to be on our guard againſt the dangerous nature of the burnt air, which ariſes from charcoal of all kinds. Charcoal burns without viſible ſmoke. The air ariſing from it appears to the eye as pure and as clear as common air. Hence it is much uſed abroad by thoſe who are ſtudious of neatneſs, and cleanlineſs in their apartments. But this very circumſtance ſhould make us more watchful againſt its effects, which may prove dangerous, in the higheſt degree, before we are aware of it. The air ariſing from common crude fuel is no doubt as bad, but the ſmoke renders it diſagreeable before it becomes dangerous. The firſt ſenſation is a ſlight ſenſe of weakneſs; the limbs ſeem to require a little attention, to prevent falling. A ſlight giddineſs, accompanied by a diſtinct feeling of a fluſh, or glow in the face and neck. Soon after, the perſon becomes drowſy, would ſit down, but commonly falls on the floor inſenſible of all about him, and breathes ſtrong, ſnoring as in an apoplexy. If the perſon is alarmed in time, and eſcapes into the open air, he is commonly ſeized with a violent head-ach, which gradually abates.

But when the effect is completed, as above deſcribed, death very ſoon enſues, unleſs relief be obtained. There is uſually a foaming at the mouth, a great fluſh or ſuffuſion over the face and neck, and every indication of an oppreſſion of the brain, by this accumulation of blood. The moſt ſucceſsful treatment is to take off a quantity of blood immediately, and throw cold water on the head repeatedly. A ſtrong ſtimulus, ſuch as hartſhorn, applied to the ſoles of the feet, has alſo a very good effect.

The fifth and laſt kind of fuel is wood, or foſſil coals, in their crude ſtate, which it is proper to diſtinguiſh from the charcoals of the ſame ſubſtances. The difference conſiſts in their giving a copious and bright flame, when plenty of air is admitted to them, in conſequence of which they muſt be conſidered as fuels very different from charcoal, and adapted to different purpoſes. See Flame.

Flaming fuel cannot be managed like the charcoals. If little air be admitted, it gives no flame, but ſooty vapour, and a diminution of heat. And if much air be admitted to make thoſe vapours break out into flame, the heat is too violent. Theſe flaming fuels, however, have their particular uſes, for which the others are far leſs proper. For it is a fact, that flame, when produced in great quantity, and made to burn violently, by mixing it with a proper quantity of freſh air, by driving it on the ſubject, and throwing it into whirls and eddies, which mix the air with every part of the hot vapour, gives a moſt intenſe heat. This proceeds from the vaporous nature of flame, and the perfect miſcibility of it with the air.

As the immediate contact and action of air are neceſſary to the burning of every combuſtible body; ſo the air, when properly applied, acts, with far greater advantage on flame, than on the ſolid and fixed inflammable bodies: for when air is applied to theſe laſt, it can only act on their ſurface, or the particles of them that are outermoſt; whereas flame being a vapour or elaſtic fluid, the air, by proper contrivances, can be intimately mixed with it, and made to act on every part of it, external and internal, at the ſame time. This great power of flame, which is the conſequence of this, does not appear when we try ſmall quantities of it, and allow it to burn quietly, becauſe the air is not intimately mixed with it, but acts only on the outſide, and the quantity of burning matter in the ſurface of a ſmall flame is too ſmall to produce much effect.

But when flame is produced in large quantity, and is properly mixed and agitated with air, its power to heat bodies [illegible] menſely increaſed. It is therefore peculiarly proper for heating large quantities of matter to a violent degree eſpecially if the contact of ſolid fuel with ſuch matter is inconvenient. Flaming fuel is uſed for this reaſon in many operations performed on large quantities of metal, or metallic minerals, in the making of glaſs, and in the baking or

burning of all kinds of earthen ware. The potter's kiln is a cylindrical cavity, filled from the bottom to the top with columns of wares; the only interſtices are thoſe that are left between the columns; and the flame, when produced in ſufficient quantity, proves a torrent of liquid fire, conſtantly flowing up through the whole of the interſtices, and heats the whole pile in an equal manner.

Flaming fuel is alſo proper in many works or manufactories, in which much fuel is conſumed, as in breweries, diſtilleries, and the like. In ſuch works, it is evidently worth while to contrive the furnaces ſo that heat may be obtained from the volatile parts of the fuel, as well as from the fixed; for when this is done, leſs fuel ſerves the purpoſe than would otherwiſe be neceſſary. But this is little attended to, or ill underſtood in many of thoſe manufactories. It is not uncommon to ſee vaſt clouds of black ſmoke and vapour coming out of their vents. This happens in conſequence of their throwing too large a quantity of crude fuel into the furnace at once. The heat is not ſufficient to inflame it quickly, and the conſequence is a great loſs of heat. See LABORATORY.

It is a known truth, that fuel cannot conſume by means of heat alone, without the admiſſion of freſh air, and this is no way more clearly proved, than by this eaſy experiment. Let a ſtrong cylinder of iron, hollow within, be fitted with a firm ſcrew at each end; in the cavity of this cylinder encloſe a long piece of charcoal, an then ſcrew up both the ends faſt, and place the whole in a ſtrong fire; let it continue there for ſeveral hours; and when it is taken out and cooled, open it, and the piece of charcoal will be found ſtill black, in its own form, and no way apparently altered or diminiſhed.

It is plain from this, that the conſumption of fuel depends upon the rarefaction, diſlodgment, briſk agitation, and diſcharge of its inflammable vapour, by means of freſh air; and hence we have the reaſon of the known rule of extinguiſhing fires by ſmothering them.

It is provided by ſtatute, that wood fuel ſhall not be felled under the aſſize. See BILLET and FAGGOTS.

Fuller's Earth

FULLERS' *Earth*, in *Mineralogy*, *Argilla Smectis*, Waller; *Talcum fullonum*, Wern.; *Talcum Smectis*, Linn.; *Fullonia communis*, Forſt.; *Argille Smectite*, Haüy; *Terre à foulon*, Fr.; *Walker-Erde*, Germ.; *Walk-lera*, Swed.; a ſpecies of earth, which from the predominance of ſilex as a conſtituent part, (at leaſt in the varieties analyzed by Bergmann and Klaproth,) ſhould be referred to the ſiliceous genus, though Werner, guided by what he terms the characteriſtic component part, places it in the firſt diviſion of his talc genus, together with bole, native talc earth, and écume de mer. Emmerling places it in his flint genus, in the ſame manner as all the varieties of common clay are transferred by him to that genus. It is fruitleſs to enter on any diſcuſſion with regard to the place a foſſil is to occupy in a ſyſtem, before all its relations, oryctognoſtical, chemical, and geological, are thoroughly underſtood; and this is more than at preſent can be ſaid of fullers' earth, which, in common with other mineral ſubſtances, denominated from the particular uſes to which they may be applied, is, both by collectors and writers, continually confounded with other ſubſtances, eſpecially with varieties of common clay. Hence it is that we find ſo very contradictory deſcriptions of the characters of this earth. The following external characters are principally derived from the varieties found in England, in Saxony, (particularly at Roſſwein, at the foot of the Saxon Ertzgebirge) in Auſtria, Moravia, the Palatinate, Alſace, and Sileſia. Many of thoſe from other parts of Europe that we have had an opportunity of ſeeing in collections, appeared to partake too much of the nature of common clay, others of that of ſteatite, while others again exhibited characters belonging to varieties of marle.

Fullers' earth is generally of a greeniſh colour, more or leſs mixed with brown and grey, together with a portion of yellow, by which various ſhades of dirty olive green are produced; ſometimes the yellow predominates, and a yellowiſh grey appears, paſſing over (in the genuine *Lemnian earth*, which, as we ſhall ſhew hereafter, cannot be ſeparated from fullers' earth,) into whitiſh grey. It is alſo found of various ſhades of red: that of Sileſia is tile red, ſometimes ſprinkled with white and green ſpots. Often ſeveral of the juſt mentioned colours are intimately, but mechanically, mixed; which, in ſome, can be obſerved only with the aſſiſtance of a magnifying glaſs. The brown colour, both uniform and in ſpots, is generally owing to an accidental admixture of iron ochre.

It has been found maſſive only, ſometimes conſtituting whole fletz-ſtrata. Large maſſes, on being ſeparated, generally diſunite into ſmaller pieces, when expoſed to the influence of the atmoſphere.

Internally it is more or leſs dull; its fracture being earthy, generally of a fine grain: often it appears perfectly conchoidal, and even ſlaty; but commonly the fragments are indeterminately angular and blunt-edged, and in the latter caſe perfectly opaque: in the pureſt varieties the edges are ſometimes tranſlucent. When ſcratched with the nail of the finger, or cut with a knife, it becomes ſmooth and ſhining.

It is very ſoft, almoſt friable, and mild; feels more or leſs greaſy, and ſcarcely adheres to the tongue. It does not ſoil. Specific gravity about 2.

Genuine fullers' earth does not effervеſce with nitrous acid; nor are all varieties of it inſtantly reduced into powder by that acid. But ſmall pieces put into water almoſt inſtantly crumble into conical heaps of minute, very ſoft particles, without producing a crackling noiſe, as is the caſe with bole; neither does a foaming take place, as has been copied by moſt authors from Cronſtedt, who attributes this quality to a fullers' earth found at Oſmund in Dalarne.

Though fuſible *per ſe*, it requires a high degree of heat: that of Hampſhire, according to Klaproth, melted in the charcoal crucible into a denſe, dark-grey, opaque ſlag, which had loſt 0.25 of its original weight, and contained many grains of iron. In the clay crucible the ſame was reduced to a cloſe, blackiſh, green ſlag, with ſoft, reddiſh, punctated ſurface. Mr. Brongniart ſays, that of Woburn melted into a ſlaggy maſs at 120° of Wedgewood's pyrometer. The variegated kind of fullers' earth (according to the late Mr. Wiedenmann's experiments,) acquired before the blow-pipe a grey, or greyiſh black colour; and a whitiſh variety, thus acted upon, became ſtill whiter: but neither of them manifeſted any ſigns of fuſion, except at the ſharp edges of the fragments. The ſame appears to hold good with all genuine varieties of this mineral ſubſtance; whence the obſervation of the late Mr. Fichtel, that the true fullers' earth "melts with great eaſe before the blow-pipe, often with ebullition and increaſe of its bulk," is undoubtedly founded in error.

Bergmann was the firſt who analyzed what he ſtyles fullers' earth, from Hampſhire; and all ſubſequent mineralogical writers have followed him in mentioning that part of England as producing the ſubſtance in queſtion: it is, however, probable that the accurate Swediſh chemiſt was miſinformed as to the county; though, from the ſatisfactory deſcription he gives of its external characters, it is ſufficiently evident that he operated on an Engliſh fullers' earth. The reſults of his analyſis were

Silica - - -	51.80
Alumine - - -	25.00
Lime - - -	3.30
Magneſia - -	0.70
Oxyd of iron - -	3.70
Water - - -	15.50.

The variety lately analyzed by Klaproth, which is well aſcertained to be from Ryegate, was found to be compoſed of

Silica - - -	53
Alumine - - -	10
Oxyd of iron - -	9.75
Magneſia - -	1.25
Lime - - -	0.50
Muriate of ſoda -	0.10
Water, &c. - -	24
Kali (a trace only)	
	98.60. Klap. Beitr. vol. iv.

We are indebted to the ſame celebrated chemiſt for an analyſis of a Sileſian fullers' earth, the external characters of which agree pretty well with thoſe of the other varieties, except that its colour is tile-red, like ſome varieties of bole, either pure, or ſpotted and veined with white and green; which colours, before the blow-pipe, give way to a marbled brown. Hundred parts of it contain

Silica - - -	48.50
Alumine - - -	15.50
Magneſia - -	1.50
Oxyd of iron - -	6.50
Oxyd of Manganeſe -	0.50
Water, &c.	25.
Muriate of ſoda, (a trace only)	
	98. Klap. Beitr. vol. iv.

We mentioned above the *Lemnian earth* as a variety of the common fullers' earth; but it ſhould be underſtood that three diſtinct ſubſtan[illegible] comprized by the ancients under the name of Terra Lemnia. "Tr[illegible] ejus," ſays Galen, "ſignantur differentiæ *una* quam p[illegible]mus terræ ſacræ, quam alii nemini, præter unam ſacerdote[illegible]n, contingere fas eſt; *altera* vero ejus quæ revera Miltos eſt [illegible]ve Rubrica: utuntur autem ea potiſſimum fabri: demum [illegible]*rtia* ejus extergit; qua utuntur qui lintea et veſtes lavant, [illegible]uibus itique collibitum eſt." The nature of the three kinds of earth alluded to in this paſſage has been placed in a clearer light by Klaproth. The *ſecond* of them, called Mil[illegible]s, was a red earth applied for the purpoſe of painting. The *third* appears to be the ſame which is mentioned by Pliny under the name of *Cimolia*, as an excellent ſubſtance for fulling: but it contains no magneſia. (See CIMOLIA.) But the *firſt* of the varieties enumerated by Galen, is the true *terra ſigillata*, recommended as early as the time of Homer for the cure of infectious diſeaſes, and ſtill celebrated in the eaſt for its imputed medicinal virtues. At the time of Dioſcorides it was mixed by the prieſts with goats' blood, and marked with a ſtamp repreſenting that animal (Σφραγὶς αἰγός): and ſtill at the preſent day this ſubſtance is dug up in the iſland of Lemnos (now Stalimene,) once a year, namely, the 15th of Auguſt, the day on which the Greeks celebrate the feſtival of the aſcenſion of the Virgin; the clergy and magiſtrates, after ſeveral previous religious ceremonies, ſuperintend the excavation of this ſubſtance, which is immediately formed into ſpindle-ſhaped balls of one ounce in weight, and marked with a ſeal bearing the name of the earth in the Turkiſh language. This ſubſtance (which ſhould not be confounded with a kind of bole of the ſame name, which is generally found nidulating in baſalt and baſaltic wackes) is of a whitiſh-grey colour, with ferruginous ſpots on its ſmooth ſurfaces. Put into water, it emits air, and ſoon crumbles into a looſe heap, exactly like the common fullers' earth, to which, notwithſtanding the ſlight difference in the reſults of the analyſis, it may, according to Klaproth's opinion, be conſidered as ſubordinate. The genuine Lemnian earth contains in hundred parts

Silica - -	66.
Alumine - -	14.50
Oxyd of iron -	6.
Lime - -	0.25
Magneſia - -	0.25
Natron - -	3.50
Water - -	8.50
	99 Klap. Beitr. vol. iv.

The best fullers' earth is found in England, especially Buckinghamshire, Bedfordshire, Surry, Kent and Nottinghamshire. The following localities are likewise mentioned in the different systems of mineralogy; but we cannot vouch for the correctness of all of them, since many substances have been called by the name of fullers' earth, that, systematically speaking, appear to have no claims to it. Austria (Karlstein, Görtz); Croatia (Bellowar); France (Rittenau, Winterhausen, in Alsace, &c.); Hungary (Luefkirchen, &c.); Moravia; Neumark (Zullenzi, Droslen); Palatinate (Kleinstarz); Pomerania (Stargard); Saxony (Rosswein, Johan-Georgenstadt, Schönberg); Silesia (Riegersdorf, Nimptsch); Sweden (Osmundberg); Stiria (Cilly and Thalberg); Switzerland (territory of Zurich and Berne); Transylvania (Thorotsko); Wirtemberg (Seeburg), &c.

The geognostic relations of fullers' earth are not yet sufficiently ascertained to enable the geologist to derive any general results from them. The relative age of the different formations appears to be as little understood, as the mode in which they have originated.

In Saxony, where it is found in extensive beds, it appears to owe its origin to the disintegration of rocks of the primitive trap formation of Werner; that of Rosswein is subordinate to green stone slate. In the Upper Palatinate it alternates with layers of clay and porcelain earth. In England it occurs principally in beds, and in strata alternating with or resting on sand-stone, the geognostic relation of which is not yet determined. At Wavedon in Buckinghamshire, on the borders of Bedfordshire, where the purest sort is found, it appears to occur in the newer fletz-formation, subordinate to sand-stone. From the surface of the earth, to the depth of six feet, several layers of sand are seen of various shades of reddish, under which there is a thin stratum of sand-stone which rests on the fullers' earth. The upper part of this latter, which is in contact, and mixed with the superincumbent indurated sand, is called *clodge* by the workmen, and thrown away as useless. To this succeeds a stratum of the good fullers' earth, being about eight feet thick, and subdivided by horizontal rifts into other layers of nearly one foot and a half in thickness. There is generally a ferruginous substance deposited on the rifts, which penetrates part of the layers; and the earth, so tinged, is called *crop* by the workmen, while the part unimpregnated by it receives the name of *wall-earth*. Under the fullers' earth is a stratum of coarse white sand-stone of about two feet thickness. The English fullers' earth is of much newer formation than that of Saxony; as is that of Moravia, which appears to belong to the alluvial formation.

The principal use to which fullers' earth is applied is indicated by its name, (see art FULLING.) The quality it possesses, of depriving cloths and other stuffs of the grease and oil used in their preparation, appears to be derived more from the argillaceous than the other ingredients; and Mr. Kirwan thinks that the union of the lime and magnesia (which in Bergmann's opinion is chemically combined with the alumine, and not mechanically mixed, as in marls) is useful only as contributing to the prompt diffusibility of this earth, which particularly qualifies it for the purpose to which it is applied. Every clay that has some unctuosity, (which manifests itself by the polish it receives by being rubbed with the nail,) and the siliceous ingredients of which are very fine, may be used for fulling; but it does not follow that all such clayey earths as agree in these two characters, and in the economical advantage derived from them, should of course occupy the same place in the system. Fullers' earth was formerly an article of the greatest importance in England, whence its exportation was prohibited under severe penalties; but of late it has been superseded by other substances, particularly soap.—K.

We subjoin some observations on the subject of fullers' earth, communicated by Mr. Farey.

"This mineral is found in three places at least in the British series of strata, the uppermost of which is, in the sand strata that underlay the chalk, and are exposed to view by the great Kent, Sussex, and Surry *denudation*, (see that article,) at the foot or southern skirt of the North Downs, at various places near Ryegate, Godstone, &c. and from whence London is principally supplied with the article, though the quality of the earth and thickness of the seam (which varies much in different places) is greatly inferior to the next fullers' earth stratum, found near the lower part of the great ferruginous sand strata, (which Mr Smith has denominated the Woburn sand,) in which fullers' earth is now dug in the greatest perfection, at Hogstye-end in the parish of Waverdon, Bucks, near Woburn. Formerly it was dug also in Aspley Guise parish, in Bedfordshire adjoining, but the works there are discontinued. Below this stratum of fullers' earth, which sometimes proves of seven feet in thickness for some distances together, is a singular greenish chertz stone, with a rhomboidal fracture, which seems very characteristic of this stratum. In distant counties, like Lincolnshire, wherein we have examined it, about Bolingbroke, and to the N. and N W. of that place, we find this and the accompanying strata very similar to those of Bedfordshire, although the fullers' earth is here so thin and imperfect in its quality, as not to be known by that name, but rather as a clay seam which holds up their springs of water in the sand district. It may also be worthy of remark respecting this fullers' earth stratum, that petrified or siliceous wood occurs in the ferruginous sand and sand-stone below it in great plenty and perfection, and furnishes most of the perfect specimens of this kind from Aspley, Crawley, and other places near Woburn, which are to be met with in the cabinets of the curious. How the stories of the petrifying springs at Aspley which occasioned them, as it is said, came first into circulation, we are unable to trace; but certain it is, that the inhabitants of this village disclaim any knowledge of such springs or petrifying waters, except what books and credulous travellers have brought to them. It has often occurred to the writer of this, that there might, at some period of the earth's formation and consolidation, have been a connection between the *silex* which abounds in such quantity and so very minute a state of division in the fullers' earth, and that which has so perfectly taken the place of the pieces of wood, lodged in the sand below it, and perhaps filled the interstices of the chertz sand-stone above mentioned; but that such took effect, in too gradual a manner to be ever noticed as a petrifying spring on the surface, as the stories above mentioned have maintained. The examination of some hundreds of specimens of this petrified wood in Aspley and Crawley, some many feet in length, and a foot or more in diameter, has not seemed to furnish data for referring any of them to the known woods of the present race, or to contradict the theory advanced in our article COLLIERY, of such being part of the arboriferous trunks of sub-aqueous vegetables of the primitive creation, whose *reliquia* they are, and by which alone their existence can ever be known to us, and not fragments of any of the trees which, now, or at any period, did occupy or grow upon the *dry land* of our globe.

"In Somersetshire and other counties, a stratum occurs between the rocks of the Bath free stone strata, which is there called fullers' earth, and possesses its scouring properties;

as indeed other ſtrata do which are not called fullers' earth, particularly one in the aſſemblage of ſtrata below the chalk, called the chalk-marl; from which a ſaponaceous whitiſh clay is got, and uſed by the country people for extracting greaſe, ſcouring greaſy kettles, &c. There are doubtleſs other ſtrata in the Britiſh ſeries which poſſeſs theſe properties, in a greater or leſſer degree, but the modern improvements in chemiſtry and the arts have rendered fullers' earth, of even the beſt quality, of comparatively ſmall importance, to that which it had when particular ſtatutes were judged neceſſary for prohibiting its exportation, under the ſevereſt penalties.

"Fullers' earth has been deemed abſolutely neceſſary to the well dreſſing of cloth; and hence foreigners, though they can procure wool to be clandeſtinely exported out of the kingdom, can never reach to the perfection of the Engliſh cloths, &c. without fullers' earth, which is very plentiful in England, and excels that of other countries in quality, as much as in quantity and cheapneſs. For this reaſon it is made a contraband commodity; and the export made equally criminal with that of exporting wool."

This earth is reckoned by ſir H. Plat, and others, a great improver of land; and conſequently proper for being uſed as a manure where it is found in ſufficient quantity for that application. It is probably the moſt adapted to the more light ſorts of land.

FULLER'S *Thiſtle*, in *Agriculture*, the common name of a plant cultivated in the field in ſome diſtricts, for its uſe by the manufacturers of ſome ſorts of cloth, as affording a fine vegetable hook, &c. See TEASLE.

Fullery & Fulling

FULLERY, a work-houſe, or place where cloths, &c. are fulled or ſcoured. The term is principally underſtood of the fulling-mill.

FULLING, the art or act of cleanſing, ſcouring, and preſſing cloths, ſtuffs, and ſtockings, to render them ſtronger, cloſer, and firmer; called alſo *milling*. See BLEACHING.

Pliny, lib. vii. cap. 56. aſſures us, that one Nicias, the ſon of Hermias, was the firſt inventor of the art of fulling: and it appears by an inſcription quoted by ſir G. Wheeler, in his travels through Greece, that this ſame Nicias was a governor in Greece in the time of the Romans.

The fulling of cloths, and other ſtuffs, is performed by a kind of water-mill; thence called a *fulling or ſcouring-mill.*

Theſe mills, excepting in what relates to the mill-ſtones and hopper, are much the ſame with corn-mills. And there are even ſome which ſerve indifferently for both purpoſes; corn being ground, and cloths fulled, by the motion of the ſame wheel.

Hence in ſome places, particularly France, the fullers are called *millers;* as grinding corn, and milling ſtuffs, a the ſame time.

FULLING *Mill*, in the *Manufactures*, is a machine employed for waſhing, ſcouring, or fulling of cloth, either with a view of cleanſing it, in which caſe it is termed ſcouring, or for the purpoſe of thickening woollen cloth, worſteds, &c. when it is termed milling; in either caſe the fulling-mill employed is the ſame: its operation is to conſtantly agitate and expoſe a new ſurface to the action of water or other menſtrua, with which the goods to be operated upon are conſtantly ſupplied; this is performed by two beaters or mallets, which are ſucceſſively raiſed by the action of a water-mill, or ſteam-engine, and let fall upon the cloth, which they ſtrike and turn over in the trough where it is placed; a conſtant ſtream of water paſſing through it, carries away the dirt and impurities which are looſened from the cloths by the agitation of the mallets, or ſtocks, as they are termed.

An inſpection of *Plate* XXIX. *Mechanics*, will give a clearer idea of the conſtruction of this machine. Here *fig*. 4. is a perſpective view of a pair of ſtocks, or fulling-mill, in the action of ſcouring a piece of goods; the other figures are explanations of the parts of the machine by a ſection, *fig*. 5, and elevation, *fig*. 6. A fulling-mill generally contains four, ſix, eight, or ten pair of ſtocks, according to the quantity of work it is required to perform; theſe are all moved by the ſame water-wheel, or ſteam-engine: in the former caſe, the axis of the water-wheel is employed to move two or three pair, whilſt the others receive their motion from one of two ſimilar and parallel ſhafts, turned by cog-wheels from the ſhaft of the water-wheel. A portion of this ſhaft is repreſented at A in the plate, beneath the floor of the mill; and the cog, which gives it motion, is denoted by N, *fig*. 4: it revolves upon gudgeons at its ends, which are ſupported on braſſes reſting on the frame work or maſonry, as ſhewn in *fig*. 6. Four levers or lifters, B, B, D, D, are fitted upon the ſhaft which alternately, as they paſs the beaters E and F, lift them up, and they deſcend by their own gravity: theſe beaters are formed from a large block of wood E and F, affixed to a long ſtem G, moving on a centre at *g*, which is ſupported at the top of the frame H I K of the whole machine; the principal part of this is a large block of wood H I, hollowed out into a large cavity *a a*, for the reception of the cloth; this is termed the trough. K are pieces of wood fixed to the piece H I, and curved to a ſegment of a circle ſtruck from the centre *g*, on which the beaters move; in the ſpaces between theſe beams the ſtems G of the beaters project ſo as to be intercepted by the lifters B, D, as they revolve; the beaters are alſo curved at the loweſt ſide to the ſame circle as the beams K, ſo that they apply as cloſe as poſſible to each other without touching; this is neceſſary to prevent the cloth getting between them, and being pinched or cut thereby. The ends of the beaters, which act upon the cloth, are armed with three ſmall boards at *h*, *i*, and *k*, *fig*. 5. which project like teeth, and act more effectually to bend and diſturb every portion of the cloth placed in the trough *a a*. The beaters act very cloſe to each other ſideways, that the cloth may not introduce itſelf between them; and in the ſame manner they fit the ſides of the trough, formed by boards nailed to the block H I, and the beams K, which alſo give a great ſtrength to the machine. At one ſide theſe boards are not ſo high, for the convenience of taking the cloth out of the trough; but when the machine is in action a moveable board M, *fig*. 4. is placed on the top of the loweſt ſide, to raiſe it to the ſame height with the other, and prevent any danger of the cloth getting over. R is a pipe bringing water to the trough, and furniſhed with a ſtop cock to regulate the ſupply; the pipe paſſes through the back of the block H I, and the water ſtriking againſt a board *x*, placed before the aperture, it falls down in a ſheet upon the cloth, and keeps it conſtantly ſaturated. When the cloth is to be put into the machine, a workman with a lever ſupported on an iron hook *k* receives the beater when at the higheſt point of its motion, and prevents its deſcent; he then thruſts a long iron bolt *r*, *fig*. 6. through a hole in the beams K, and by that means retains it; the other beater is then taken up in the ſame manner, and re-

tained by the same bolt, being pushed farther forwards; the loose board M is now removed, and the cloth thrown into the trough *a a*; the beaters are then set in motion by removing the bolt *r*, which held them up. As the shaft A revolves, the lifters alternately engage one or other of the beaters which falls against the cloth, and, striking it at the under side, thrusts it up into the curved part of the trough *a a*, and by that means it falls down upon the head of the beater; when the lifter raises the beater another time, the cloth falls into the space left by its being raised; in this manner it continues turning the cloth over in the trough, and striking it by its teeth *h, i, k*, so as to wash it thoroughly. As the two beaters fall alternately, that is, one is up when the other is down, the cloth is also turned round diagonally in the trough: by this means, after milling a piece of cloth for some hours, there is little chance but that every part shall be subjected to the action of the beaters, though a whole piece is in action at once, and consequently folded in innumerable creases. The water which enters at the upper end of the trough beneath the loose board *x*, (which is intended to spread the water out into a thin sheet, that it may fall equally upon the whole of the cloth,) escapes slowly through the grooves between the beam K, in which the stems G move, carrying with it all the filth contained in the cloth; it falls into a pit represented by the dark space in *figs*. 5. and 6. in which the shaft revolves. This pit usually has a communication with the water of the mill, to wash away the sediment which accumulates in the pit, from the foul water continually falling into it. The machine is fixed over this pit by a tennant at the lower part of the block H I, which is bolted between two beams L, L, supported on masonry; M are two braces to sustain the ends of the beams K, and keep the whole machine firmly in the same position: the beams L, L, are extended to a considerable length, and have three or four machines placed parallel to each other between them.

The true method of fulling with soap is delivered by Mons. Colmet in an authentic memoir on that subject, supported by experiments made by order of the marquis de Louvois, then superintendant of the arts and manufactories of France. The substance of which we shall here subjoin.

FULLING, *Cloth and woollen Stuffs, with Soap, Method of*. A coloured piece of cloth, about forty-five ells, is to be laid in the usual manner, in the trough of a fulling-mill, without first soaking it in water, as is commonly practised in many places.

To full this trough of cloth, fifteen pounds of soap are required; one half of which is to be dissolved in two pails of river or spring-water, made as hot as the hand can well bear it. This solution is to be poured by little and little upon the cloth, in proportion as it is laid in the trough: and thus it is to be fulled for at least two hours; after which it is to be taken out, and stretched.

This done, the cloth is immediately returned into the same trough, without any fresh soap; and there *fulled* two hours more. Then taking it out, they wring it well, to express all the grease and filth.

After the second fulling, the remainder of the soap is melted, as the former, and cast, at four different times, on the cloth; remembering to take out the cloth every two hours, to stretch it, and undo the plaits and wrinkles which it has acquired in the trough. When they perceive it sufficiently fulled, and brought to the quality and thickness required, they scour it out for the last time in hot water, keeping it in the trough till it be quite clean.

As to white cloths; because these full more easily, and in less time, than coloured ones, a third part of the soap may be spared.

FULLING *of Stockings, Caps, &c.* may be performed somewhat differently; viz. either with the feet or the hands; on a kind of rack, or wooden machine, either armed with teeth of the same matter, or else with horses or bullocks' teeth.

The ingredients made use of herein are urine, green soap, white soap, and fullers'-earth. But water softened with chalk is far preferable.

Note, woven stockings, &c. should be fulled with soap alone; for those that are knit, fullers'-earth may be used with the soap.

Indeed, it is frequent to full these kinds of works with the mill, after the usual manner of cloths, &c. But that is too coarse and violent a manner, and is apt to damage the work, unless it be very strong.

FULLING, in the *Manufacture of Hats* is the completion of *felting* (which see), and has for its objects the intimate connection of the fibres, and a more perfect and durable cohesion of the whole mass. For this purpose the mere mechanical act of pressure is insufficient. In this way the result would be a formless mass, without consisten[illegible] perience (says Chaussier, cited in Nicholson's [illegible]nal, vol i.) has long shewn, that for the fulling it is [illegible]y to make use of a bath of water heated near to ebullition, into which are put 10 or 15 pounds of lees of wine, for each hundred pounds of water. The heat is kept up during the whole time of working, and every three or four hours a new quantity of lees is added. Into this bath the workmen plunge their felt, and begin their second process. The felt is dipped in, and immediately again taken out and squeezed, bended and rolled, by pressure in different directions, sometimes with the hand defended by leather, and sometimes by means of a roller or other similar instrument. The immersion and working of the felt are repeated, and the operation continued, till the stuff is well condensed, and has acquired the requisite solidity.

Since the operation of fulling is employed to form a dense and compact stuff with the fibres or hairs, and to determine the intimate cohesion of its component parts; and since the mere mechanical operation is not sufficient for this purpose, even with the assistance of a water-bath at the boiling heat, without the addition of lees as a necessary condition;—this last must be considered as a chemical solvent, which acts directly on the substance of the hairs themselves, and produces, either by softening or swelling them, an alteration necessary to insure the cohesion of the different fibres of the stuff. But the lees being composed of the mucilaginous and colouring parts, which are separated, together with a great quantity of tartar, or the acidulous tartrite of pot-ash, it became necessary to ascertain, in a positive manner, what might be the principle of its action. The editor of the Encyclopedié affirms without hesitation, that it is the alkali or pot-ash of the lees which determines the fulling. But in order to shew (says Mr. C.) how erroneous this assertion is, nothing more is necessary than to dip a piece of blue paper into the bath, by which the former becomes instantly red; and if, after several hours' work, the state of the bath be again examined, it is found that the acidulous tartrite of pot-ash is partly exhausted, and the workmen soon perceive, from the difficulty of continuing their work, that a new quantity is required to be added. And again, if we consider the sparing solubility of the acidulous tartrite of pot-ash in cold water, it is easily seen why in this process the water must be kept nearly boiling. Whence

it is evident that it muſt act by the portion of acidate which it contains. Hence our author was induced to think, that the ſulphuric acid might be advantageouſly ſubſtituted in the place of the lees; and as 12 pounds of lees are uſually added to 100 of water, he eſtimated by approximation that one gros of ſulphuric acid would be equivalent to at leaſt one pound of the lees, and conſequently that 12 gros of ſulphuric acid would be ſufficient for 100 pounds of water. His conjectures were ſoon confirmed by experiment; and after a fair trial it was aſcertained that the uſe of the ſulphuric acid is much preferable to that of wine-lees; that it is not only much more economical, but ſtill more convenient in the uſe; and, what is yet more important, the health of the workman is not injured by the exceſs and duration of the heat, the thick vapours, and the diſguſting odour, which exhales from the bath, particularly when the lees have been altered by mouldineſs and putrefaction, which is very common in theſe manufactories. When the ſulphuric acid is employed, it is uſeleſs to keep the bath nearly boiling, as was formerly done. A degree of heat of 25 or 30 degrees (90 or 100 of Fahrenheit) is ſufficient for good fulling. The ſaving of fuel is an object of importance in manufactories; and as very little fire is neceſſary when ſulphuric acid is uſed, cauldrons of lead may be ſubſtituted inſtead of copper-boilers, the firſt coſt and annual repair of which are very conſiderable.

The felts prepared by this new proceſs are alſo of a very ſuperior quality to thoſe which have been worked in the bath with wine-lees. In fact, the mucilaginous and colouring matters of the lees, which are ſuſpended in the bath, penetrate the texture of the ſtuff, and adhere with more or leſs force; and when, after having paſſed the hats through the dye, they are beaten, a fine black duſt flies off in great abundance, which not only weakens the texture of the felt, but by diffuſing itſelf through the manufactory greatly incommodes the workmen, and frequently occaſions coughs and diſorders of the throat.

Hats felted in this manner, ſays a manufacturer who had adopted this proceſs, are not only clear of the powder which abounds in the others, but they take the dye better, and are cleaner.

Furnace

FURNACE, an utenfil, or veffel, proper to contain fire, or to raife or maintain a vehement fire in, whether of coal or wood.

There are divers kinds of furnaces, of various forms, and for various ufes.

The domeftic furnace, ufed in making confections, &c. is ufually of iron, or earth.

Thofe ufed by the goldfmiths, refiners, &c. are much larger, and of a different ftructure.

Thofe wherein lime, bricks, &c. are burnt, are called kilns.

FURNACE, in general, means a veffel or place in which high, or long continued heat can be applied in chemiftry, in the arts, and domeftic economy, and thefe are either fixed or portable.

Furnaces are principally divided into two kinds, thofe which act by the draught of a chimney and called *air* or *wind furnaces*, and thofe in which the air is forced in by bellows and called *blaft* furnaces. But before we give defcriptions of the different furnaces ufed in various chemical and other operations, we fhall give a brief outline of their general principles, firft premifing that furnaces commonly confift of three diftinct parts; a body, or cavity to contain the fuel, a chimney to carry off the heated air and fmoke, and a receptacle under, and feparated from the body by a grate, and called the afh-pit. Although the conftruction of furnaces is a fubject of the greateft importance to thofe employed in chemical and metallurgic operations, we yet do not find that any chemift or other philofophical writer has given principles, or any thing like a theory, from which rules might be deduced for the conftruction of a furnace of any kind, that fhould with certainty fulfil its intention; and a perfon, wifhing to build a furnace, has hitherto had no other guide than that of taking the exact dimenfions of fome other furnace, that by mere guefs has been fo conftructed as to act well. One fact we may ufe as a general rule, that is, that fince the heat is generated by combuftion, it muft be the greateft when the greateft quantity of fuel is confumed in the leaft time, and when the fuel is in fufficient quantity, the heat will be in proportion to the quantity of oxygen paffing through the fire in a given time.

In fuch a furnace as we have juft pointed out, with a view to define the parts, if the fire be kindled, the air in that part will become fpecifically lighter, and will therefore afcend; the place of the afcending air muft be fupplied from below, and if there be no opening below, but through the grate, all the oxygen which enters muft contribute to the increafe of the combuftion.

Every increafe of heat will give an additional levity to

the air, and for a certain length of time the heat will continue to increafe till it arrives at its maximum.

The velocity with which heated air afcends is as the difference of fpecific gravity between that of the atmofphere and the heated air. The principles on which the motion arifing from a change of fpecific gravity may be referred to the cafe of two weights hanging over a pulley. If they are of equal weight no motion is produced, but if one be increafed, or the other diminifhed, the heavy one will defcend and the light one afcend, with a velocity proportionate to their difference.

If the fum of the weights be W and their difference P, then, according to Mr. Atwood's theorem, which he confirmed by experiment, the velocity at any point will be $\frac{P}{W}$ multiplied by the velocity which a body would acquire by falling freely through the fame fpace.

The rifing or falling of bodies in different fluids may be referred to the fame calculation, by fubftituting their fpecific gravities for the abfolute gravity of the weights.

Let 1 = the denfity of the furrounding air,

d = the difference of temperature between the furrounding and heated air in degrees of Fahrenheit,

P = the number of degrees of Fahrenheit required to double the bulk of a given quantity of air,

h = the height of the chimney,

S = the fpace a body will fall through in a fecond of time,

v = the velocity of the afcending air: then the increafe of bulk in the heated air will be $1 + \frac{d}{P}$, and the denfity, compared with the furrounding air, will be $\frac{P}{P + d}$. The difference of denfity will be $1 - \frac{P}{P + d} = \frac{d}{P + d}$, and the fum of their denfities $\frac{2P + d}{P + d}$; then $\frac{d}{P + d} \div \frac{2P + d}{P + d} = \frac{d}{2P + d}$. This fraction, agreeable to Mr. Atwood's theorem, multiplied into the velocity a body would acquire by falling through h, will give the velocity of the afcending air;

$S : 4S^2 :: h : 4Sh$; then $2S^{\frac{1}{2}}h^{\frac{1}{2}}$ will be the velocity a body would acquire by falling through h.

Hence $\frac{d}{2P + d} \times 2S^{\frac{1}{2}}h^{\frac{1}{2}} = v$, the velocity of the afcending current.

In finding d, let the temperature at the bottom of the chimney = B; that at top T; and let the temperature of the air which enters at the grate be M: then $d = M - \frac{B + T}{2}$.

The above theorem will require an equation for the friction of the tube, which will be very great in chimneys made of brick. It is plain that if it were not for the friction of the tube, the velocity would be as the fquare root of the height, all other things being equal.

In order to afcertain how far the friction of the tube affects the ratio of the fquare root of the height, I took (fays the writer of this article) an iron tube of one foot long and two inches in diameter, having a funnel-fhaped mouth, at the lower end, four inches wide, and about the fame length. At the top of the tube was placed a fmall paper fly, with its axis vertical, fo that it might be turned by the rifing current, in a manner fimilar to the fly of a fmoke jack.

I found that a very fmall change of temperature was capable of putting the fly in motion. And that keeping both my hands upon the outfide of the funnel, at the fame time that there was free accefs of air into its mouth, I had conftantly about 45 revolutions made by the fly in a minute. Reckoning the difference of temperature, or d, 45 Fahrenheit, which was about the fact, it would give by the theorem above ftated the velocity about $\frac{4}{5}$ths of a foot per fecond, which was near the truth.

The fly was then removed and placed at the top of the tube, lengthened to four feet. The velocity in this inftance by the theorem fhould have been 75, but did not exceed five, fo that the defect produced by the friction was .25. It would appear, therefore, that every increafe of velocity, by increafing the height of the tube given by the theorem, may be divided by two, to reduce it to experiment. For the retardation by the friction, and the acceleration of its rifing, are in the fame ratio, that is, as the fquare root of the height. If, however, the velocity be increafed by the change of temperature, or as d, then the friction will be increafed in a greater ratio; for the friction is as the fquare of the velocity. Therefore, if the velocity be twice as great from increafing d, the friction will be four times as great. Hence the height of a chimney cannot increafe the power of a furnace only to a certain extent, fince the friction, after a certain limit, would prevent the acceleration, and bring the velocity to an uniform motion.

By other experiments I found that the manner in which the air enters the mouth of the tube is of fome confequence. When the mouth of the funnel was held about two inches above the furface of a table, the current up the tube was hardly fufficient to put the fly in motion, and it would not begin to move till the mouth was elevated four or five inches. If, however, one-half the funnel refted upon the table, and the other over the edge of it, the fly went at the rate of 45 revolutions in a minute. When the funnel's mouth was covered with paper, having a hole in the middle equal to the area of the tube, 47 revolutions were produced; but when the whole mouth was expofed about the fame height above the floor, it produced 49 revolutions.

It appears, therefore, that when the air can afcend freely and perpendicularly to the entrance of the furnace, it is to the greateft advantage.

Since, agreeably to the nature of our theorem, the velocity of the current muft depend upon the difference of temperature between the internal and external air, the air entering the furnace ought to be as cool as poffible. A furnace, therefore, fhould be fo fituated, that its air may be fupplied from a cellar below, into which its afh-pit fhould terminate. This cellar fhould be as fpacious as poffible, and the afh-pit fhould be at leaft four times the width of the furnace, reckoning from the grate to the floor; but the higher the better, becaufe the air, as we have before ftated, is fupplied with fo much more facility in a perpendicular direction.

The grate of an air-furnace confifts of a number of fingle bars, having fhoulders at each end, fo that when they are laid fide by fide, bringing their fhoulders together, the interftices between the bars may be nearly equal to the breadth of the bars. The diftance between the bars is here rather more than is in common ufe, but for producing great degrees of heat, this account will be found to anfwer in practice. The bars are merely laid upon two bearers placed in the brick work at right angles to the bars; one of the bearers being loofe for the purpofe of fliding backwards to let all the bars fall down with the fire. Without this con-

trivance, after any process is finished, the fire would have to burn itself out, and it would be much more troublesome to clean the furnace when it is choaked with slag.

The height of the fire-place must be suited to the purpose to which the furnace is applied. If it is a melting furnace, the height must be such that the fuel may be about half the width of the furnace above the top of the crucible, the latter being raised about ¼th the width of the furnace above the grate.

The chimney of an air-furnace should be as wide as the sum of all the interstices through which the air enters the fire, allowing nothing for friction; but as this is very considerable, at least that ought to be double, so that the chimney should never be less than half that of the furnace.

The height of the chimney is the next consideration. In the present state of our knowledge we have no exact rule for the height of chimneys of furnaces. Indeed it will depend upon so many circumstances, that it would be difficult to give this statement exactly; since, however, the height is limited by the friction, it will be important to avoid all those circumstances on which the friction depends. The principal of these are, the roughness and narrowness of the chimney. The velocity of the ascending air will be inversely as the width; and the friction will be as the square of the velocity. It is equally certain that the friction will be much increased if the chimney be rough in the inside, but more particularly when it is crooked, or when the air is interrupted by having to move in any other direction than that of a perpendicular one.

When, therefore, the chimney consists of an upright prism or cylinder, having its interior surface as smooth as possible, it must act to the greatest advantage possible.

If the chimney be made of brick, those sides of the bricks intended to form the interior of the chimney should be rubbed to make them smooth, and laid with fine well-tempered fire clay, that the interior surface may be free from cavities and other inequalities.

If the chimney consists of iron lined with clay, it should consist of lengths of about two feet each. After each of the pieces are lined and well dried, but not hard baked, the inside should be scraped or rubbed, to give them greater smoothness. By this means the height of the chimney may be increased to advantage beyond the ordinary height; since the above pieces or lengths may be fitted together and separated with the greatest facility, and the maximum of height may be easily ascertained by experiment.

Another very important circumstance ought to be attended to in the contruction of chimneys. The air which is heated in passing through the fire should retain its heat, if possible, till it clears the top of the chimney. Although this cannot be effectually accomplished, it may be effected as far as the non-conducting power of the materials of the chimney will admit.

Common bricks are very bad conductors, and consequently not well adapted for chimneys. But some fire-bricks of loose aggregation are still better calculated to retain the heat.

The best method, however, of making perfect chimneys, is first to build one of very close, smooth bricks, making the internal surface as above directed. This should be surrounded with a second chimney, leaving a cavity between the two about the breadth of a brick. This cavity should be filled with powdered coak, or, what is better, powdered charcoal. The heated air would retain its original temperature much longer in such a chimney, which would admit of its being carried higher, and increase the draught.

The chimneys of portable furnaces are generally made of rolled iron. These chimneys carry off the heat so rapidly, that the height is very soon limited, and beyond that point becomes an evil. It has been recommended by Lavoisier to make the chimney of a double iron tube, and fill up the cavity with powdered charcoal. By this means, however, the internal tube would become so hot as to be easily acted upon by the air, and by sulphuring the fuel consequently would soon be destroyed. If the cavity between the two tubes were to be filled with a soft composition of equal parts of lime, clay, and sand, making the c[illegible] between the tubes about half the width of the inner tube, an earthen tube would be formed, which would form an excellent chimney, [illegible] after the interior tube of iron was destroyed. The furnace itself, being lined to a proportionate thickness with the above composition, would make [illegible] portable air-furnace [illegible] of heat.

In those air-furnaces, where the fire-place is required to [illegible] open at the top, such as *Plate* II. *fig.* 3, the chimney is required to be connected with the fire-place by an horizontal channel called a flue. This flue must always be considered as an impediment to the draught of a furnace, and ought never to be used but where the separation of the chimney from the fire-place is absolutely necessary. From the experiments [illegible] it will appear that the air of a furnace should ascend as perpendicularly as possible; hence a horizontal [illegible] ought in all cases to be avoided, and it will be equally evident that the evil will be still greater when the air has to descend, as in the furnace *Plate* II. *fig.* 3. In all furnaces, therefore, where the fire-place is intended to be separated from the chimney, the flue should be made to ascend as much as possible by making an obtuse angle with the side of the furnace instead of a right one, as in *Plate* I. *fig.* 1. Various opinions have been advanced relative to the width of the flue. When we consider, however, that the flue is a part of the chimney, all opinions must give way, for if the flue is not as wide as the chimney the air must have to move with a proportionally greater velocity in that part, and in the same degree lessen the draught of the furnace. Hence the flue should be the width of the chimney as near as possible.

Although in strictness all furnaces are air-furnaces, yet, as we have above said, they are usually distinguished into those where the air is forced through the fire by bellows, and those where the air enters by what is called the draught of the chimney.

These are again denominated either from their construction, or the particular uses to which they are applied, as will be seen in the course of this article. Generally speaking, the furnaces used in chemical operations, and for melting and refining metals, are of the latter kind or air-furnace; and we shall now proceed to describe the parts and particular uses.

Furnace, *Air*. An air-furnace, calculated to produce great degrees of heat, particularly adapted for a melting furnace of the fixed kind, and possessing all the advantages to be given to it, is represented in *Plate* I. *fig.* 1; *a* is the ash-pit of the furnace; *b* the grate; *c* the fire-place; *d* the cover, which consists of an iron frame filled up with fire brick. The cover slides sideways to open the furnace; *g e* is in place of the flue of the common air-furnace, but here is made a part of the chimney *h*. The part *e f g* may be taken away without injuring the furnace, and the roofs may be employed for many purposes, such as roasting substances, fitting crucibles upon it before they are introduced into the furnace; and occasionally a cupel may be set upon it, for the purpose of assaying metals, having at the same time a small opening in the cover *d*, for the purpose of admitting air. This furnace will be found much more powerful in not having a contracted flue, and at the same time making an obtuse

angle with the ſide of the furnace. From what has been previouſly obſerved, the high aſh-pit will contribute much to its action. It is alſo recommended that the chimney ſhould be double, and the interſtices filled with powdered coak.

Fig. 2. repreſents a ſection of a portable air-furnace, adapted to general purpoſes: *a b* is a frame of caſt iron ſtanding on three legs; *c* a diſh of rolled iron for the aſhes to fall into; *a o* the top of the frame, has a hole in the centre a little wider than the fire-place, into which the grate is fitted; *d* is a groove paſſing quite through the frame, a little wider than the hole in the middle, and immediately under the grate. Different pieces of ſheet iron are made to fit this groove, having different fixed openings for the purpoſe of regulating the draught. One of them, however, has no opening, and is intended to ſhut out the air entirely. The openings in theſe regulating ſlides being in the centre, the air will enter the furnace perpendicularly, and its paſſage will be much facilitated by the height of the grate from the floor, and by the air having a free acceſs on all ſides to the furnace.

i k is the fire-place; *e* the cover, conſiſting of either one round brick made on purpoſe, fitted into an iron frame, or of ſeveral pieces fitted into the ſame. The outſide of the furnace is made of rolled iron, lined with a compound of two parts clay, two of coarſe ſand, and one of lime. The chimney is alſo of rolled iron, and conſiſts of double tubes, *n s* and *p q*, rivetted to the outſide of the furnace. The cavity between the tubes is filled with the above-mentioned compoſition. The other parts of the chimney, when it is required to increaſe its height, may be made in pieces of about two feet in length, conſiſting, like the parts attached to the furnace, of a double tube, and the cavity filled up as before directed. The inner tube muſt be a little ſhorter than the outer tube, ſo that the additional length of the outer tube may form the joint in putting the chimney together. A hole is made in the body of the furnace at *i*, and a ſimilar one on the oppoſite ſide, for the purpoſe of introducing a tube through the furnace, which is required in many experiments. A ſlit is alſo made in the furnace at *k*, for the purpoſe of introducing the neck of a retort. The hole and ſlit above-mentioned have correſponding plugs made of the ſame ſubſtance as the lining of the furnace, by which theſe openings are cloſed when not wanted. There is another opening at *g* fitted by the plug *h*: this is uſed for the introduction of fuel when it is not convenient to introduce it at the mouth of the furnace. Occaſionally, alſo a ſmall muffle may be introduced into it at this opening, the other end of the muffle reſting upon the part *s*.

The cover being removed, a ſand-bath ring may be introduced, ſimilar to that in Dr. Black's, *Plate* II. *fig.* 7.

When a retort is introduced, and the bottom does not happen to be ſupported by the ſand, it is liable to move, and ſometimes to be broken, by reſting entirely upon the neck. This inconvenience may be remedied, by paſſing a ſolid plug through the furnace at *i*. This plug may be made by coating a piece of iron with a compound of very pure clay and ſand, to render it as infuſible as poſſible, ſince it will be expoſed to the greateſt heat of the furnace. The middle of this ſupport muſt contain a receſs to receive the bottom of the retort. When all the openings are cloſed, and a ſlide introduced at *a*, having an opening equal to the width of the furnace, this furnace will be found a moſt powerful melting furnace; and, by introducing different ſlides, it may be employed where the moſt moderate heat is required.

The air-furnace repreſented in *Plate* I. *fig.* 3, is principally intended for enamelling and aſſaying in the cupel, where the excluſion of every thing but the air of the atmoſphere is particularly neceſſary: *a b* is an iron frame, ſimilar to that of *fig.* 2, having a groove at *d*, for the ſliding plates to regulate the draught, and a tray at *e* to receive the aſhes; *g a y o* is the body of the furnace, made of rolled iron, and lined ſimilar to that of *fig.* 2, leaving the ſpace *m n* for the fire-place; *g p* is a dome connected at *p* by a ſliding hoop, with the chimney *w*; *s* is a circular damper; *f* is a muffle, having a plug at *e*; *t* is the ſtrong earthen tube ſtanding upon the grate, having an opening, *t*, quite through it, which correſponds with a ſimilar opening in the bottom of the muffle. This tube alſo ſerves as a ſupport for the muffle; *x* is an opening through the coating of the furnace, correſponding with a ſimilar hole in the end of the muffle. The end of the muffle is made convex, ſo as accurately to fit the ſide of the concave fire-place. Hence, a current of air will paſs up the tube, *t*, into the muffle, which will eſcape at the opening, *x*, into the chimney *l*. This current can be regulated by the circular damper *q*. The plug, *e*, is only to be taken out to inſpect the proceſs, the damper, *q*, being at the ſame time ſhut to prevent the entrance of cold air into the muffle.

On each ſide of the dome are two openings, ſuch as *h*, having plugs to fit. Theſe are for the purpoſe of introducing fuel during the aſſaying proceſs.

The advantages of this furnace, for the purpoſe of aſſaying, are obvious, ſince it can be regulated to the greateſt nicety. When the current of cold air tends to cool the muffle, or the heat of the furnace is deficient, the damper, *q*, can be ſhut more or leſs; and if the heat is too great, that at *q* may be opened, and *s* ſhut to any degree.

This furnace may very eaſily be converted into a melting-furnace, or even to one for general purpoſes. The dome *g p*, and the muffle *f*, being removed, and a cap put upon the mouth of the chimney *w*, the furnace having a cover ſimilar to that of *fig.* 2: the plug, *y*, being removed, will form the flue, the opening, *x*, being of no conſequence, particularly when the damper, *q*, is ſhut; and a plug muſt be introduced at *e*, where the muffle was taken out. The chimney may be lengthened from the part *z* by pieces ſimilar to thoſe recommended in *fig.* 2.

An air-furnace, on the common plan, is repreſented in *Plate* II. *fig.* 2, in which *a c* is the fire-place; *c* the grate; *b* the cover; *d* the flue; and *e* the chimney. This furnace differs from the air-furnace already deſcribed only in the contraction of the flue, and the aſh-pit.

A fixed air-furnace, invented by Mr. Knight, is ſhewn in *fig.* 3: *a b* is the fire-place; *b* the grate; *c* the entrance for the air under the grate; *e* is the flue; *f* a cavity or chamber, for the purpoſe of baking crucibles, and other uſes; *y* the paſſage for the air into the chimney *h*; and *i* is a ſliding damper. Although this furnace poſſeſſes great conveniences, it is not calculated for producing the greateſt degrees of heat, ſince the air muſt meet with much obſtruction in its paſſage from the fire-place to the chimney. *Fig.* 4. is a furnace invented by Mr. Muſhet, intended as an experimental furnace for the purpoſe of aſſaying ores, &c.: *a b c d* is a cylinder of caſt iron, lined with fire-bricks, ſo as to conſtitute the fire-place *e f*; *y* is the grate having a receſs in the middle for the reception of a crucible ſtand; *s* the aſh-pit; *o* is the flue, and *g* the cover: *b i* is a rod of ſteel faſtened into the bottom of the caſt iron cylinder at *b*, and having at the other end an index *i k*, fitted to the arc *q r*, which is attached to the cylinder. When the furnace is uſed, the exceſs of expanſion of the ſteel rod above the caſt iron cylinder will give motion to the index, and if the arc be graduated, ſo as to correſpond with Wedgwood's pyrometer, the degree of heat, in any experiment, will be known. In order to prevent the ſteel rod, which is poliſhed, from oxydation, it is incloſed in a tube of

iron, and the cavity filled up with powdered charcoal. The fire-place, from the grate to the cover, is three feet; the diameter at the grate ten inches, and at the top nine inches. The height of the chimney, the inventor recommends, should not be less than thirty feet, and the width nine inches throughout.

Although this furnace has not been generally adopted, the thought is very ingenious, and, no doubt, practicable, to a certain extent. The scale would most likely require to be altered from time to time; first, from the change in the expansibility of the steel rod; and, secondly, from the increase of the conducting power in the bricks. These objections may be much obviated by attending to these changes. At all events, the pyrometer will enable the operator to find the relative heat, should it even fail in measuring the absolute degrees, which will certainly be a great acquisition.

Dr. Black's reverberatory air-furnace is shewn in *Plate* II. *fig*. 1: *a b* is the fire-place; *b* the grate; *c* the cover; *a e* is an horizontal cavity through which the flame reverberates, and passes up the chimney *l*; *d* is a door for introducing the materials to be operated upon.

This furnace is used for roasting various substances, such as the ores of metals, for the purpose of expelling their volatile matter. It may be also employed for the cupellation of metals, the door *d* being a little opened for the admission of atmospheric air.

Fig. 5. is a representation of Mr. Knight's portable air-furnace; *a b* is the fire-place; *b c* the ash-pit, which is closed on every side, excepting at the register door, where the air is admitted; *o* is an opening for the reception of fuel; *e* is a recess for the neck of a retort. *Fig*. 9. is a dome fitting the top of the furnace, to which the tube *fig*. 10. is connected, which unites with another tube inserted into a common chimney. *Fig*. 8. is a sand-bath, which is used in the absence of the dome, and, like it, is connected with the tube 10.

This furnace is made of rolled iron, and lined with an earthy composition. *Fig*. 6. is a perspective view of Dr. Black's portable air-furnace, which, but for its confined ash-pit, has not as yet been improved upon: *a b* is the fire-place; *b c* the ash-pit; *e* a sliding door for the admission of fuel, &c.; *d*, another door for the same purpose, and also for the introduction of a muffle. *Fig*. 11. is a cover, and *fig*. 7. a sand-bath; *f* is a chimney, which is lengthened by pipes of rolled iron, or connected by the same with another chimney. This furnace, like the last, is made of rolled iron, and lined with clay and sand.

Another air-furnace, of great power, and very convenient for operations, has been constructed and employed by Mr. Mushet in his numerous and valuable experiments on iron and steel, a portion of which he has communicated to the public through the medium of the Philosophical Magazine: he has obligingly furnished us with the drawing and description. *Plate* III. *fig*. 1. is the section of an assay or melting, and annealing, and also a small reverberatory furnace for fusing in very high heats with the flame of pit-coal. A is the assay-furnace; B the reverberatory furnace; and C the annealing, or cementing-furnace.

The assay-furnace is cased in cast iron, with a flanch projecting inward, the breadth of a brick, and about half an inch more, which serves instead of bearers for the bars. (See *fig*. 2. at D.) Upon this flanch the brick-work is reared; it ought to be of good fire-bricks on the bed; the furnace is nine inches square; total height 27 inches; from the top of the flanch, to the bottom of the flue, the interval is 18 inches; the flue is four inches high; the height above is five inches; flue seven inches long, and keeps opening into the chimney, as may be seen in *fig*. 3, at E. If the chimney is under 25 feet in height, a larger flue is requisite; and if beyond 35 feet, a smaller flue will throw the heat more regularly through the furnace. In general, however, more harm ensues from too small, than from too large a flue. G is the floor-line, and also represents the edge of a grate which covers the ash-pit, which is better seen in the ground-plan, *fig*. 3, and in *fig*. 2, at H. This grate lies nine inches from the bars, leaving an open space for the admission of air; it projects 24 inches outwards, and serves the operator to stand upon.

II, in *figs*. 1 and 2, is the ash-pit; in *fig*. 3, which is a ground plan of the chimney and furnaces, C is the annealing, or cementing-furnace, in which the crucibles are annealed, or baked, to a bright red heat, and from thence introduced, along with the matter to be operated upon, into the assay-furnace. It also serves instead of a cementing-furnace, being easily made to produce a heat of 100 of Wedgwood: it may be made of any size, from 9 to 14 inches square, a 9-inch chimney being sufficiently wide to the extent of an 18-inch furnace.

The chimney to each furnace is carried up five feet perpendicular; they then gradually incline to the centre opening, which they enter about twelve feet above the flues: L, L, L, are dampers: from the grates of this assay-furnace, to the top of the chimney, the interval is 33 feet.

This furnace has melted 400 grains of malleable iron in ten minutes; and half a pound from lumps in 40 minutes. If the materials to be operated upon are prepared with judgment, any experiment, to the extent of half a pound of matter, may be performed in half an hour, and less quantities in much less time. When approaching to its highest heat, a Stourbridge clay crucible (which drop in 168 of Wedgwood,) will disappear in 15 minutes, from the time that it is put in. The first five bring it to 140 of Wedgwood, at which cast iron boils. Steel boils in it at 162°, and malleable iron boils at 170° to 172° of Wedgwood. It is probable, however, that the advantages of this furnace do not result from the height of the chimney, (which is not great,) or from the size of its opening; more, it is likely, depends upon the flue; the opening of the grate bars; the size of the fuel; and particularly the feeding of the fire.

Furnace, *Almond*, or *Alman*. This is also called a sweep, and is used for separating metals from cinders, slag, broken tests, crucibles, &c. See Sweep.

Furnace, *Assay*. The furnaces above described may all be used for assaying or cupelling, see *Plates* I, II, III.

Furnace, called *athanor* or *tower* furnace. This was a construction of air-furnace, calculated to preserve an equable degree of heat for a considerable length of time; it was much employed by the alchemists and chemists of the last and preceding century in their tedious and repeated distillations, calcinations, &c. but is not at present in use.

Furnace, *Balling*. See Iron.

Furnace, *Bellows* or *Blast*. Having given an account of the principles, and described the varieties of air, or draught furnaces, we shall give some account of those furnaces which are supplied with their air by mechanical means, and are called blast-furnaces. This part, however, will not comprise those on the large scale for smelting iron, as that subject has been amply treated under the article Blast-*Furnace*. We shall, therefore, confine ourselves to the smaller blast-furnaces employed in chemical experiments requiring great and sudden heat.

It will appear, from what has been observed respecting the principles of furnaces, that if the ash-pit of a common air-furnace were made perfectly close in every part, excepting through the grate, and an opening into the ash-pit into which the nozzle of a pair of double bellows may be in-

serted, a blast-furnace would be found differing from an air-furnace only in the mode of forcing the air into the fire. Indeed its action would be so similar to that of an air-furnace, that it might for most purposes answer the same end.

The blast-furnace for philosophical experiments was much improved by the ingenious Dr. Lewis, who fitted up a black-lead crucible for this purpose. The pot chosen should be of the largest size, and if a cover or dome, or an additional part be wanted, another pot with a portion of its lower narrow part sawed off makes a very convenient one. A round plate or slip sawed off from the solid part of the bottom serves very commodiously both for a grate and for a support to the crucible; eight or nine holes, about three quarters of an inch in diameter, are bored round the outer part of the plate for the transmission of the air forced in by the bellows, which holes are made to widen downwards to prevent their being choaked up by pieces of the fuel. The air was forced in by bellows by an aperture on the side of the pot.

In operations which require a considerable degree of concentrated heat, it has been proposed to impel a number of flames into one point by streams of air driven from different parts of the circumference of the fuel to the middle by means of several bellows placed round the furnace. But a number of bellows being incommodious, Dr. Lewis has contrived to multiply the stream of air from one bellows. The pot which serves as a furnace for this purpose has a number of holes bored at small distances in spiral lines all over it, from the bottom up to such height as the fuel is designed to reach to.

The crucible is placed on a proper support in the bottom; and the holes are obliquely directed towards the crucible, so that the impelled heat plays in a kind of spiral upon its surface. The pot which serves for the blast furnace already described, with an iron ring at the top, receives this perforated pot so far, that all its holes are within the cavity, which cavity has no other outlet than the round aperture for the bellows; and therefore the air thus blown in will distribute itself through the perforation of the inner pot.

Mr. Arthur Aikin has considerably improved upon this plan of Dr. Lewis's, and the following is a description of his furnace, as published in the Philosophical Magazine.

Plate IV. *fig*. 3. is a view of a section of this furnace. It is formed of three black-lead crucibles. The 1st, *a*, is a crucible cut off near to the bottom, leaving a portion of the internal cavity; the 2d, *b*, is what contains the fire and the crucible. The bottom of this crucible is perforated with holes for the admission of air, as shewn at *fig*. 4, which is blown into the cavity in the base part *a*, by double bellows. The stand of the crucible has a projecting part which fits a hole in the bottom of the crucible *b*, in order that it may stand more firmly (see *fig*. 5.); *c* is a third crucible sometimes inverted upon that of *b*, when the fire requires to be heaped up higher, or to keep off the glare of light. This has a hole in the side to let out the air, and another into the bottom laterally, for the purpose of introducing an iron instrument to lift it on and off.

This furnace is particularly adapted for a lecture room, since its fire can be raised to its full heat in a very little time; at the same time it is capable of producing a greater heat than almost any other furnace.

Mr. Aikin has adapted this furnace to experiments with the cupel, by having a crucible with a hole through the bottom, and a stand having a corresponding hole through it, communicating with the cavity in the part *c*. In the inside of the crucible are several projections forming a shoulder or flange to set the cupel upon. An earthen tube is fitted into the cover extending obliquely out of the mouth of the furnace; this serves to look down for inspecting the process.

Several kinds of small blast furnaces are also used in the arts, particularly that used in melting pig iron for the purpose of casting. This furnace is called a cupola, and will be described under iron. See Iron.

Furnaces *for making Colours*, are those for subliming cinnabar or sulphuret of mercury for making vermilion; for subliming sulphuret of arsenic for making king's yellow; for calcining blood for making Prussian blue, ochre, &c. &c. For their construction and use, see the arts, and the different articles in this work.

Furnace *used for enamelling Pictures*. The extreme delicacy which is necessary in the process of firing or burning in the colours in enamel painting, renders the construction of the furnace an object of the utmost importance to the artist, whose labours are liable to be irrecoverably lost by the slightest mismanagement of the process, or error in the formation of the furnace.

We are enabled, through the kindness of Mr. Bone, of Berner street, London, enamel painter to the king and prince of Wales, to present our readers and artists of this class with a drawing of the furnace which he has employed for firing his most celebrated productions, and which, we may safely say, have not been equalled either for the richness of colour and accuracy of design, or for the size to which he has extended the paintings on enamel, which were formerly confined to the most minute subjects. The lower part of *Plate* V. contains these drawings, which are two vertical sections taken on planes perpendicular to each other; the same letters of reference applying to both. A represents the fire grate extended over the ash-pit, B, of the furnace; the fire door at C for the admission of the fuel is placed at the back of the furnace or side opposite to that where the operator is stationed, and in a separate room: this is intended that the smoke, which will at sometimes issue from the mouth of the furnace, may not endanger the pictures. The room, therefore, where the operation is performed, has no connection with the fire, so that the whole may be conducted without dust or smoke. The pictures are placed in a muffle E, which is open only at one end; it is supported upon three small arches, F, F, F, of brick-work extending across the furnace; the spaces between these form three flues, which convey the flame of the fuel beneath the muffle. The mouths of these flues are shewn by the three dark squares *fig*. 11; they then turn up over the arched roof K, of the fire-place, and under the muffle between the arches F, F, F, at the commencement of these flues shewn by dark squares in *fig*. 11, and marked *a* in *fig*. 10. The flame divides, and a part proceeds over the muffle at *b*, being reverberated upon it by the arched roof of the chamber in which the muffle is situated. After passing over and under the muffle, the two currents of flame escape together to the chimney N, through three flues *d*, which are beneath an iron chamber H, called the annealing oven. In this four shelves are fixed to contain the articles which are to be annealed, previous to being introduced into the muffle. This is done through the open end which is exposed at *e* to the open air, the junction of the muffle with the wall of the furnace being made by fire clay inserted between them. Before the mouth of the muffle an iron plate, *f*, is placed supported by brackets: this, together with the wall of the furnace, forms a table to support the picture when it is withdrawn from the muffle for examination. The muffle is made of fire clay in one piece, but it is very difficult to obtain materials which will withstand the heat when in so large a mass without cracking, which the best that can be procured

will do; frequently it, however, is not a very material defect, if a small crack takes place at the upper part, as it begets a confidence that the muffle will not crack any further, owing probably to the unequal contraction of the parts of the muffle having liberty of action.

The operation of burning in the colours of a painting, or, as it is technically termed, *firing*, is conducted in the following manner: the picture painted, and prepared as described in our article PAINTING *in Enamel*, is placed upon a planch or flat piece of fire-stone, with a small quantity of whiting between them, the use of which will be explained hereafter. These are put into the lowest shelf of the annealing oven H, and the door of the oven closed to prevent the entrance of dust. The fire is now lighted on the grate, and after burning from three to four hours, according to the state of the weather and direction of the wind, the muffle acquires a vivid white heat, and of similar appearance in all parts: when this happens it is judged proper to begin firing; the pictures in the oven in the mean time have gradually acquired such a heat as to be in no danger of cracking from the change of heat on entering the muffle; the planches have usually reached a low red heat by the time the muffle is properly hot; and it is supposed that the oil used in mixing up the colours is nearly all evaporated, the painting exhibiting a very dull and faint appearance. It is proper that the door of the annealing oven should not be too close, that the vapour from the oil may readily escape.

The planch and picture upon it are now removed from the annealing oven by an iron fork, *fig.* 7, used in a manner similar to a baker's peel, and introduced into the muffle: the doors are shut close; the operator now looks through a small hole in one of the doors, furnished with a sliding cover, and attentively watches the picture; he sees it gradually heat till it acquires the same colour as the muffle; the surface of the picture is then observed to assume a glossy appearance, arising from the fusion of the enamel; at first this commences at the farther part of the muffle, but extends itself, with astonishing celerity, over the whole surface, if the operation is well conducted. The picture is now withdrawn from the muffle upon the table before its mouth, and examined before a strong light, if every part is equally glossy; if not, it is returned to the muffle; in this state the picture and planch only exhibit a mass at a white heat; no traces of painting or colour can be discovered, and the whole judgment must be formed from its appearing equally fused in every part of the surface.

The fusing being now completed, the picture is returned to the annealing oven; and the fire being put out by taking away the bars of the fire, the whole furnace cools gradually together, the picture remaining in the oven some hours before it is removed to paint again upon it. The operation of firing a picture requires to be performed from twelve to twenty-five times, according to the tints required, and the nature of the picture: the pictures are liable to crack whilst in the muffle, an accident that cannot often be repaired, in which case the labour of painting is all lost. The principal precaution against this is to proportion the flues in such a manner that the annealing oven shall always be of such a temperature that the pictures taken from it, and introduced into the muffle, may not experience such a change of temperature as to fly. In Mr. Bone's furnace this is so well regulated, that he seldom finds his paintings crack in the firing, though it cost him many severe disappointments before he obtained this perfection by repeated trials: this disposition to crack appears to depend almost as much upon the plate and enamel as the construction of the furnace, and it is no proof because a painting stands the first firings well, that it will not fly in the succeeding. Enamel pictures are nearly all liable to cockle or warp in the firing, in a greater or less degree, though this may be obviated so far, by great care in the preparation of the metal plate, as to be no serious detriment to the effect of the pictures: the method of preparing these plates is explained in the article ENAMELLING. For an account of the colours, and art of painting, see PAINTING *in Enamel*, which is a subject requiring long experience, to be added to the usual knowledge of a painter, as the colours are in fact produced by the firing, being very different in appearance when laid on, and without any of the brilliancy for which this species of painting is distinguished The artist must judge concerning the effect which his painting will produce by his recollection of the change of each colour, and its combination with others, instead of being able to examine it constantly by its appearance: but it is essential to the perfection of enamel painting, that all the colours employed should blend together in the firing, and at the same heat, or some would be too much burnt before others were properly fused; and they must be of such a nature as not to emit any vapour when in the fire, as this would produce bubbles in the surface, and destroy the effect of the painting.

As the colours at present known which will stand these tests are but few, and require compounding together to produce the various tints, it is an additional reason why none can be admitted but such as are acted upon in a similar manner by the fire. It is conjectured that the crack in the muffle, being found rather to improve than lessen the effect, may arise from a minute draught which will take place through the muffle, carrying off any vapours proceeding from the oil, which may remain in the colours after annealing, or other causes, which vapour, if confined to the picture, might be detrimental to the colours. As the generality of enamel plates are made with the surface convex, it becomes necessary, when they are large, to support the centre of the plate from sinking, which they are very liable to do when in a state of fusion. To prevent this accident, the planch must have a bed of powdered whiting laid upon it, with its surface made to fit the concavity of the enamel plate as nearly as possible, carefully avoiding all pressure upon the plate, least it should receive any strain. If this operation is nicely conducted, the plates may be made to keep their shape much better than by any other means that have as yet been devised.

FURNACE *for enamelling watch Dial-plates.* This furnace, though very simple in its construction, differs from all the others we have described in not having any bars or grating for the admission of air to the bottom of the fire; the only passage for air being through or under the muffle, which in this kind of enamelling consists only of a simple arch of clay without either bottom or back.

This furnace is singularly adapted to the purpose for which it is used, as a very intense heat is obtained with a comparatively small quantity of fuel, in addition to which the work may be brought almost in contact with the coals without receiving any injury from their dirt; clearness in this kind of enamelling being very justly considered one of its greatest perfections. *Fig.* 1. of *Plate* V. *of Furnaces*, represents a front elevation; A, A, are two piers of brick work, upon which rest the arch B, covering the ash, or coak-pit, C. From each side of these piers project the three bricks D, D, D, which support the hearth, or iron plate, E; another plate of cast iron lies just beneath this, which serves for the bottom of the furnace, and which may be seen in the section at F, *fig.* 2. Upon this plate of iron stand the Welsh lumps, G, G, forming the interior sides of the furnace; the one which forms the back may be seen at G,

fig. 2: the brick-work is then carried upon each ſide over the piers, and bound together by the iron bar H, which likewiſe ſerves to ſupport the brick-work over the front, in which is fixed the regiſter, or damper, I. When the furnace is completed thus far, the flue may be carried up to a convenient height, or turned into one already formed.

To give the reader a clear idea of the method of uſing this furnace, as well as the way in which the fuel ſhould be placed, we have given, *fig.* 2, a vertical ſection through the line C I, perpendicular to the front; and that the parts in each may be compared, we have uſed the ſame letters of reference as far as the parts could be ſeen in each figure.

When the fire is to be made up for uſe, the muffle is to be placed in the furnace; one end reſting on the iron ſupport, as ſhewn at K, *fig.* 1, and the other end is to be kept level with the front by putting a piece of coak under each ſide. The ſpace on each ſide is then to be filled with ſmall pieces of coak, and at the back of the muffle ſmall coak muſt likewiſe be put in till it reaches about half way up the end. A ſolid piece of coak muſt then be ſelected, which muſt be large enough to cover the end of the muffle, and upon this a ſecond piece muſt be placed to ſupply the place of the firſt when that is burned away. The ſpace then immediately above the muffle muſt be filled with middling ſized pieces of coak, carefully building it up in the front, ſo as to keep it even with the ſides G, G. The door, as ſhewn at *fig.* 3, is then to be placed in the front, preſſing it cloſe up to the ſides G, G. To light the fire, nothing more is neceſſary than to fill the ſpace under the muſſle with red-hot charcoal, and by drawing the damper a good way out the fuel will ſoon be alight all over. In *fig.* 2. it will be found that we have endeavoured to ſhew the poſition of the fuel placed in the order of our deſcription, with a ſection of the muffle ſhewing the height of the charcoal which lies at the bottom when the fire is in a ſtate fit for uſe. For we muſt here obſerve that it will be always neceſſary to beat that pretty ſmoothly down, that the apparatus which the dial lies on may be placed ſteadily upon it.

As it would be difficult in this figure to ſhew the poſition of the dial-plate in the fire, we have given, at *fig.* 8, a ſection of the apparatus as it is placed under the muffle; *a* being the dial-plate; *b b*, the ring; *c*, the planch; *d*, the turner. In uſing theſe, the turner is firſt placed ſteadily upon the bed of charcoal, and the dial, being placed upon the ring is laid as nearly as poſſible in the centre of the planch, which is conveyed under the muffle, and placed upon the turner with the ſpring tongs, as ſhewn at *fig.* 6. When one ſide of the plate is nearly melted, the planch may be turned round by a ſlight touch with the tongs, till the whole dial is completely fuſed all over, when it muſt be withdrawn from the furnace, and placed juſt in the front of the muffle to cool gradually.

Fig. 4. is an end elevation of the muffle placed on the prop, as ſhewn at *fig.* 1.

Fig. 5. is a vertical ſection of the ſame through the line *a b*.

Fig. 9 is the iron key with an aperture in the end, which fits the ſquare pin, *e*, in the door, as ſhewn at *fig.* 3, and is uſed to remove the door from the front of the furnace when it is hot.

FURNACE, *Founders*, is of different forms, according to the kinds of works to be caſt. See FOUNDERY and IRON.

FURNACE, *Glaſs-Houſe*. See GLASS.

FURNACE *for Glaſs-Painters*. See PAINTING *on Glaſs*.

FURNACE, *Hatters*. See HAT.

FURNACE, *Lamp*. See LAMP.

FURNACE, *Letter Founders*. See LETTER-FOUNDERY.

FURNACE, *Melting*. See *Air*-FURNACE.

FURNACE, *Plumbers*, is of three kinds: in the firſt they melt the lead, whereof ſheets are to be caſt. This is only a ſort of large copper, or receptacle like a copper, made of free-ſtone, and coated well round with clay, having a little iron pan at the bottom. In the ſecond, they melt the lead to be caſt in moulds for pipes, &c. which are not to be ſoldered. The third is the tinning furnace, which is a ſquare frame of wood, or ſometimes a maſs of ſtone-work, with brick hearth, whereon is made a charcoal fire, which ſerves them for the applying of thin tin leaves on the works. See PLUMBERY.

FURNACES *for baking Porcelain and Pottery*. See KILN and PORCELAIN.

FURNACES, *Portable*. See above, Knight's, Black's, Lewis's, Muſhet's, Aikin's, &c.

FURNACE *uſed for baking Tobacco-pipes*. We may, perhaps, be criticiſed for introducing into our plates the implements of ſo trifling a manufacture, but we ſhall excuſe ourſelves, on account of the ingenious ſtructure of the furnace, and the application which may be made of it to other and more important purpoſes. This furnace is to be admired for equality of the heat in every part of the crucible, or pot, in which the pipes, or other articles to be heated, are placed, at the ſame time that the flame is not permitted to enter, ſo as to ſoil the articles it contains. This crucible is marked A A, *Plate* III. *figs.* 4 and 5: it is of a cylindrical figure, terminated at the top by a hemiſphere; it is placed over the fire-place, B, and encloſed within a furnace, D D, of brick-work, lined with fire-brick E E: between this lining and the crucible is a ſpace of about four inches, all round in which the flame from the fire-place circulates, without interruption, except what ariſes from the numerous ſupports which are neceſſary to ſuſtain the crucible in its proper poſition; but as theſe are always placed edge-ways to the flame, and are very thin, they cauſe but little obſtruction to its action: the ſupports are 12 ribs, between the crucible and the lining, which form the ſame number of flues, as ſhewn by the dotted lines *x*, *fig.* 5, (the dotted circle A being the crucible): the ribs are perforated with occaſional apertures, (ſee the ſection, *fig.* 4.) to connect one flue with the adjoining; but the principal bearing of the crucible is taken from five piers, *b b c*, formed of bricks, projecting one over the other: one of theſe piers, *c*, is placed at the back of the fire-place, and the other four at the ſides *b*, *b*, and projecting at the top, nearly into the centre of the crucible, ſo as to ſupport and ſtrengthen the bottom of it, which reſts upon theſe piers, the ſpaces between which form the mouths, or commencement of the flues ſurrounding the crucible: at the top of the crucible all the flues unite in the dome, L, of the fire-brick lining, and this has a circular opening through it, leading into the chimney N.

The lining, F E E, of the chimney is open on one ſide, (ſee the plan,) to form the door, at which the pipes are taken in and out of the furnace; the opening is permanently cloſed as high as *k*, *fig.* 4, by an iron plate plaſtered with fire-clay; above this it is left open, and only cloſed when the furnace is burning by temporary brick-work: when this is removed, the furnace can be filled or emptied through the opening; and, for this purpoſe, the crucible has a ſimilar opening in its ſide: when the furnace is burning, this aperture is cloſed, by an ingenious contrivance: the workman firſt ſpreads a layer of clay round the edge of the opening; he then ſticks the ſtems of broken pipes acroſs, from one ſide to the other, and plaſters the interſtices with clay in a manner exactly ſimilar to the lath and plaſter uſed in building. The whole of the crucible is made in this manner; the bottom is compoſed of a great number of fragments of pipes, radiating to

the centre; these are coated with a layer of clay at the circumference; a number of the bowls of broken pipes are inserted into the clay: in these, other fragments are placed upright, to form the sides of the crucible. The ribs round the outside, which form the flues, are constructed in the same manner, as is also the dome, L, of the fire-brick lining; by this means the crucible can be made very strong, but at the same time so thin, as to require but little clay to construct it, and is less liable to split by the heat, than a vessel formed of thicker materials. This method might, we think, be advantageously applied in other cases, where a very thin vessel or lining is required for a furnace. The pipes which are to be baked are arranged within the crucible, as shewn in the section, the bowls resting against the circumference, and the other ends supported upon circular pieces of clay, *r*, which are set up in the centre for that purpose; six small ribs are made to project inwards, all round the crucible, at the proper heights, to support the different ranges of pipes, without having so many resting upon each other, as to endanger their being crushed by the weight. By this mode of arrangement, the furnace is made to contain 50 gross, or 7200 pipes: these require to be burned from seven to nine hours; and the heat is at first brought on gently, and afterwards increased to the full heat required for baking this species of pottery: the fire is regulated by a simple kind of damper applied over the aperture in the dome, L, of the fire-brick lining. This is a mixture of horse-dung, sand, and pipe-clay, well worked together, and spread in thin layers upon coarse brown paper: a sheet of this being laid over the hole in the dome, so as to cover more or less of it, will give the means of increasing or diminishing the draught, and, consequently, the heat of the furnace.

We shall conclude this article with some useful hints relative to the different kinds of fuel, the management of furnaces, and the quality and form of crucibles.

The fuel employed is of three kinds; namely, pit-coal, coak, and charcoal; the first of which is seldom employed but for reverberatory furnaces, where substances are to be heated by flame, or heated air. The nature of coaks varies according to the manner of preparing them, and the nature of the coal. For some purposes, such as melting steel, or in other situations, where long continued and intense heat is required, the coaks are made so hard as to exhibit a bright, white, crystalline fracture. In other cases, where great heat is not required, and where expedition is more an object, the soft coaks are preferable. When a clear fire, free from smoke, and the suffocating vapour of sulphurous acid, from pit-coal coak, is required, charcoal is found exceedingly convenient. Charcoal is also sometimes mixed with coak, for the purpose of making the coak kindle more speedily.

When coak, or pit-coal, is employed, the grate is liable to be choaked, from the fusion of the earthy matter with which it mostly abounds. An iron rod, with a hook at one end, is used for removing this substance from the grate, which otherwise would prevent the passage of the air. After an air-furnace has been used for several hours, when the fire is let out, the bars ought to be taken out for the purpose of removing all the slaggy matter.

Nothing, perhaps, is of more importance, in the dry operations of chemistry, than good crucibles. Formerly we had no good crucibles but what came from Holland, and those termed Hessian crucibles. The most essential point in making good crucibles, is to get clay as free as possible from metallic oxyds, particularly iron. A crucible should be capable of bearing a heat that will thoroughly fuse the substance put into it, without becoming itself so soft, as not to bear lifting out of the fire. And it should also be capable of bearing sudde. extremes of heat and cold, without cracking. The first of these objects is attained, by introducing as much pure clay into its composition as possible. Crucibles, made solely of clay, however, are very liable to crack with extremes of heat and cold. This latter evil has been avoided, by mixing the coarse powder of burnt clay with the pure clay; and sometimes for the burned clay pure white sand has been used. The crucibles used for melting steel, which requires greater heat than is generally used, are made with Stourbridge clay, and the powder of other hard coaks, which are used as fuel. These pots will sometimes bear four heats, or meltings, without cracking or losing their form.

The inside of a crucible is in figure nearly a paraboloid, and the outside a truncated cone; so that the sides are gradually thicker towards the bottom. The stands and covers of crucibles ought to be made of the same materials as the crucibles: the stand should be cylindrical, and of the diameter of the bottom of the crucible.

Previously to a crucible being put into the fire, it should be gradually heated to at least a low red heat; and a good crucible, which has been heated till it begins to vitrify, can seldom be trusted a second time in the fire.

A crucible should never be introduced, or taken out of the fire by tongs, holding it by one side only, but by such as will embrace it closely on the outside, by having the mouth of the tongs of the curvature of the crucible. When a crucible is very hot in the furnace, the fire should not be suffered to get very low, since the introduction of a great quantity of cold fuel will be liable to break the crucible. Crucibles are much more liable to crack when they have been baked very hard. If they are merely hard enough to bear putting into the fire, and to bear the weight of the materials, it is sufficient.

FURNACE

PLATE

Fig. 1.

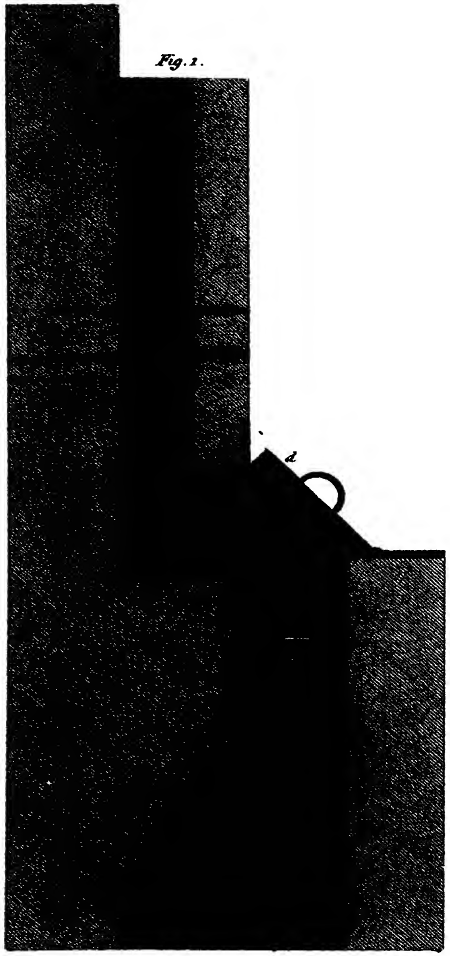


Fig. 3.

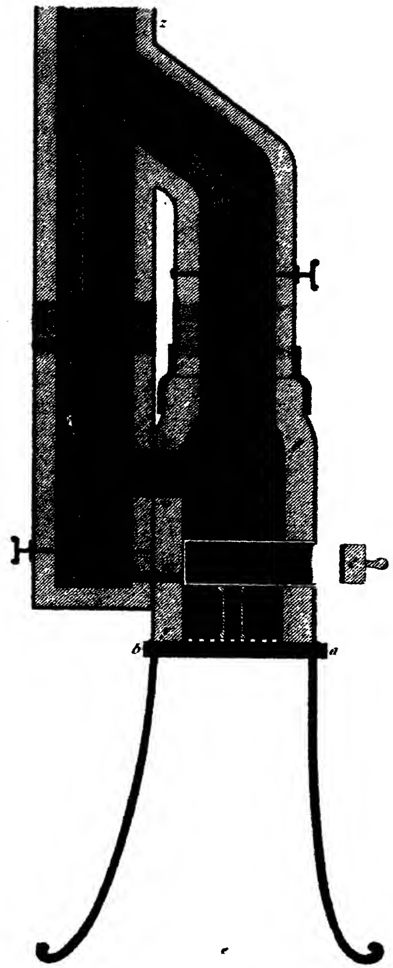
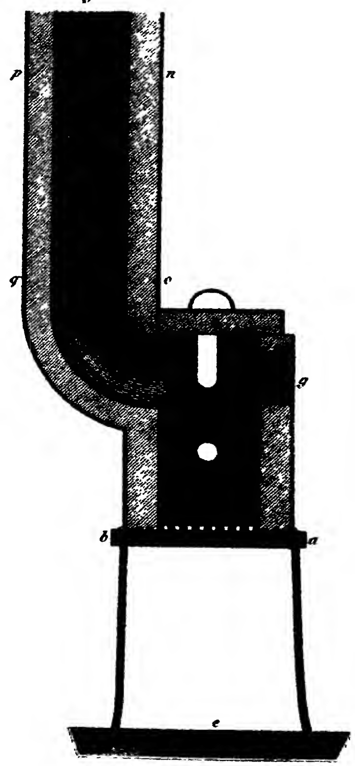
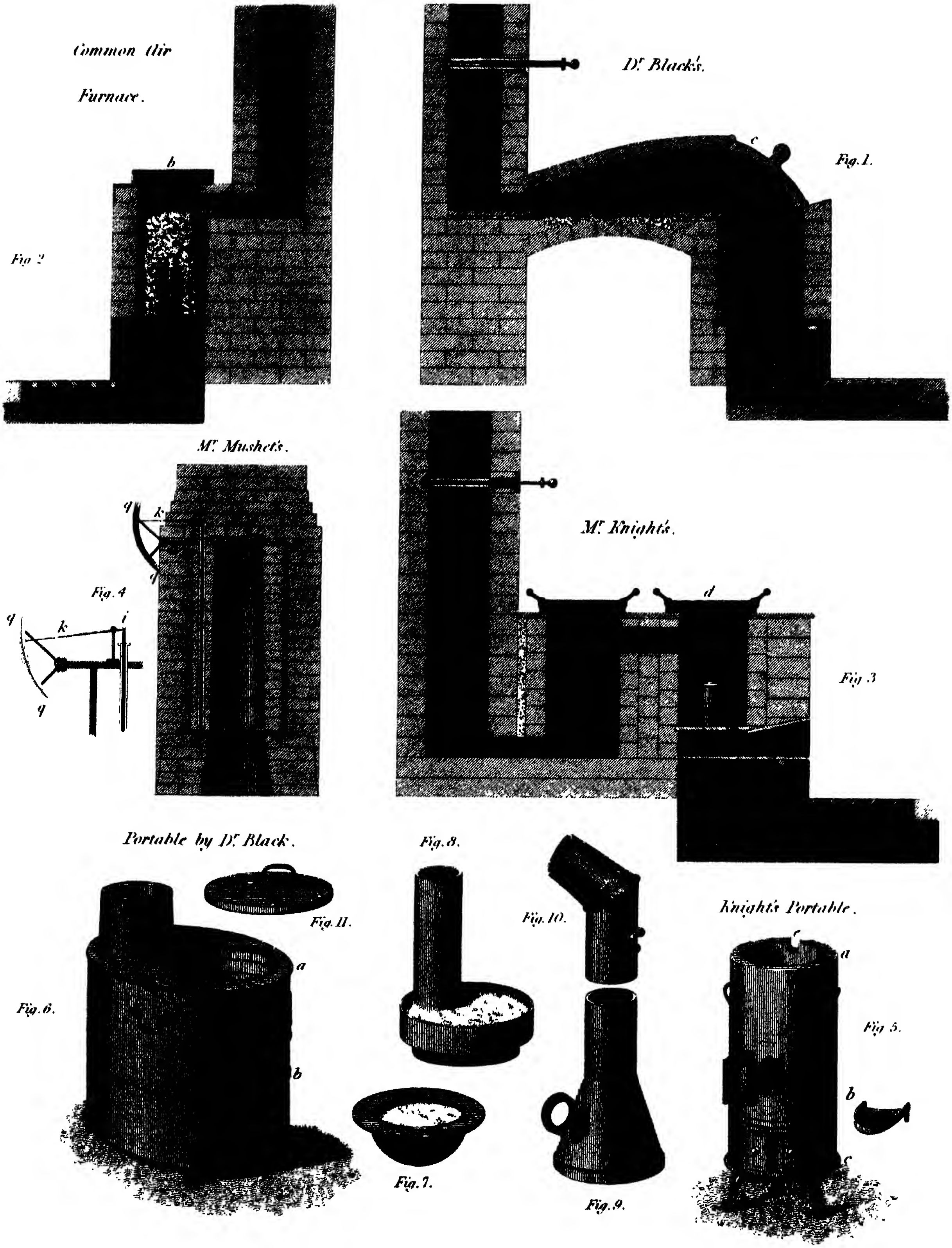


Fig. 2.





by J. Farey Jun.

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FURNACES.

PLATE III

Furnaces used by Mr. Mushet for his experiments on Iron & Steel.

Fig. 2.

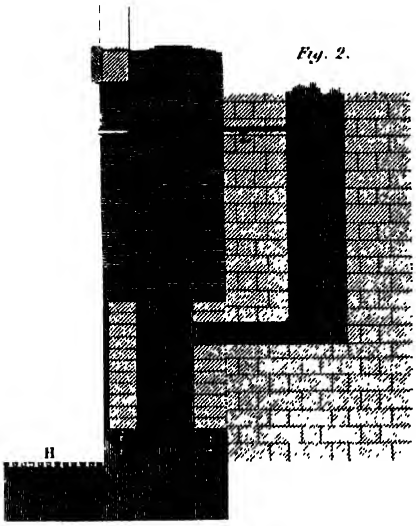


Fig. 1.

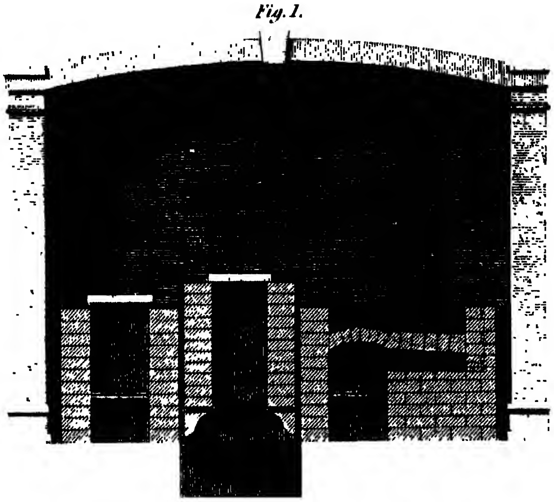
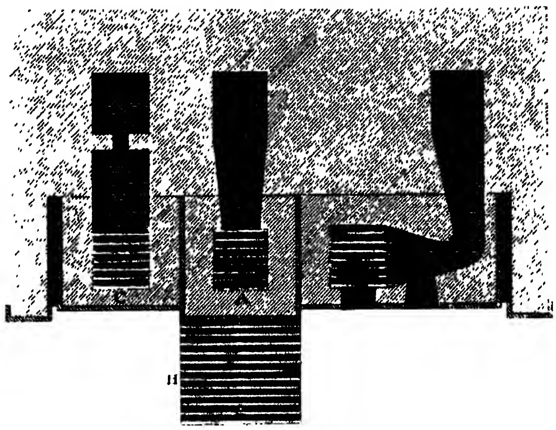
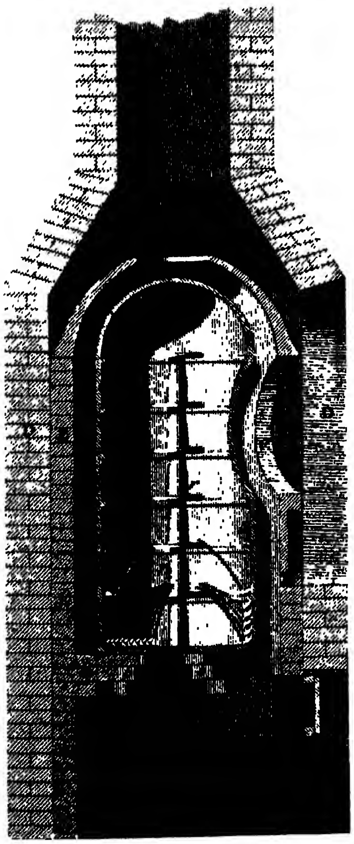


Fig. 3.

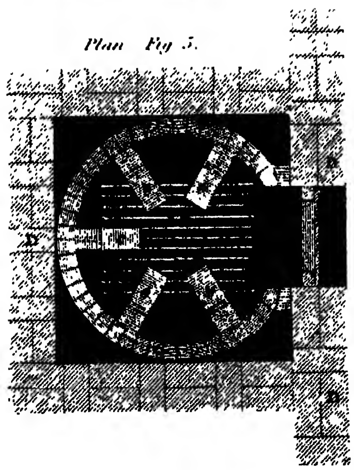


Section of the Tobacco pipe makers Furnace.

Fig. 4



Plan Fig 5.



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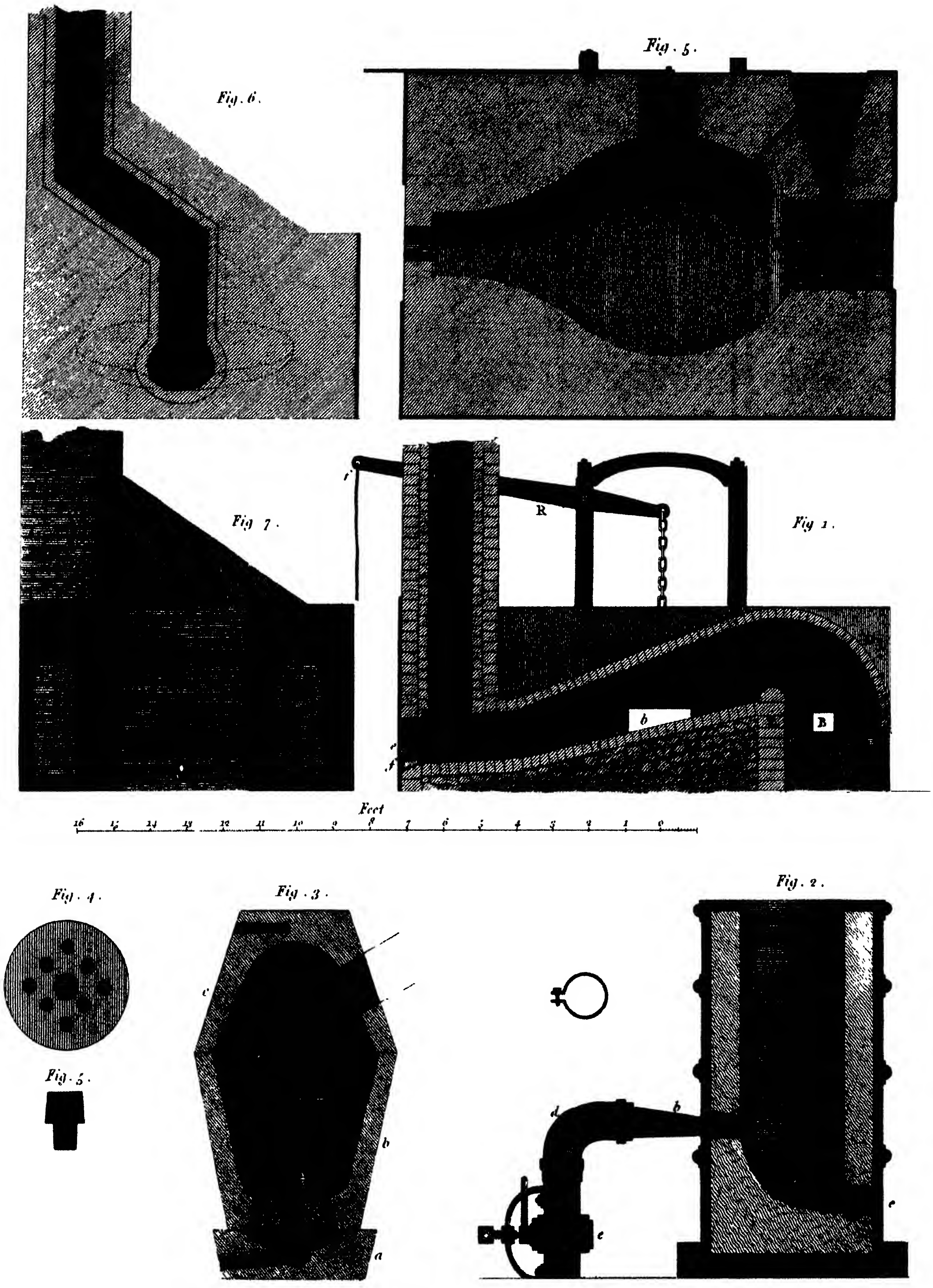
FURNACE.



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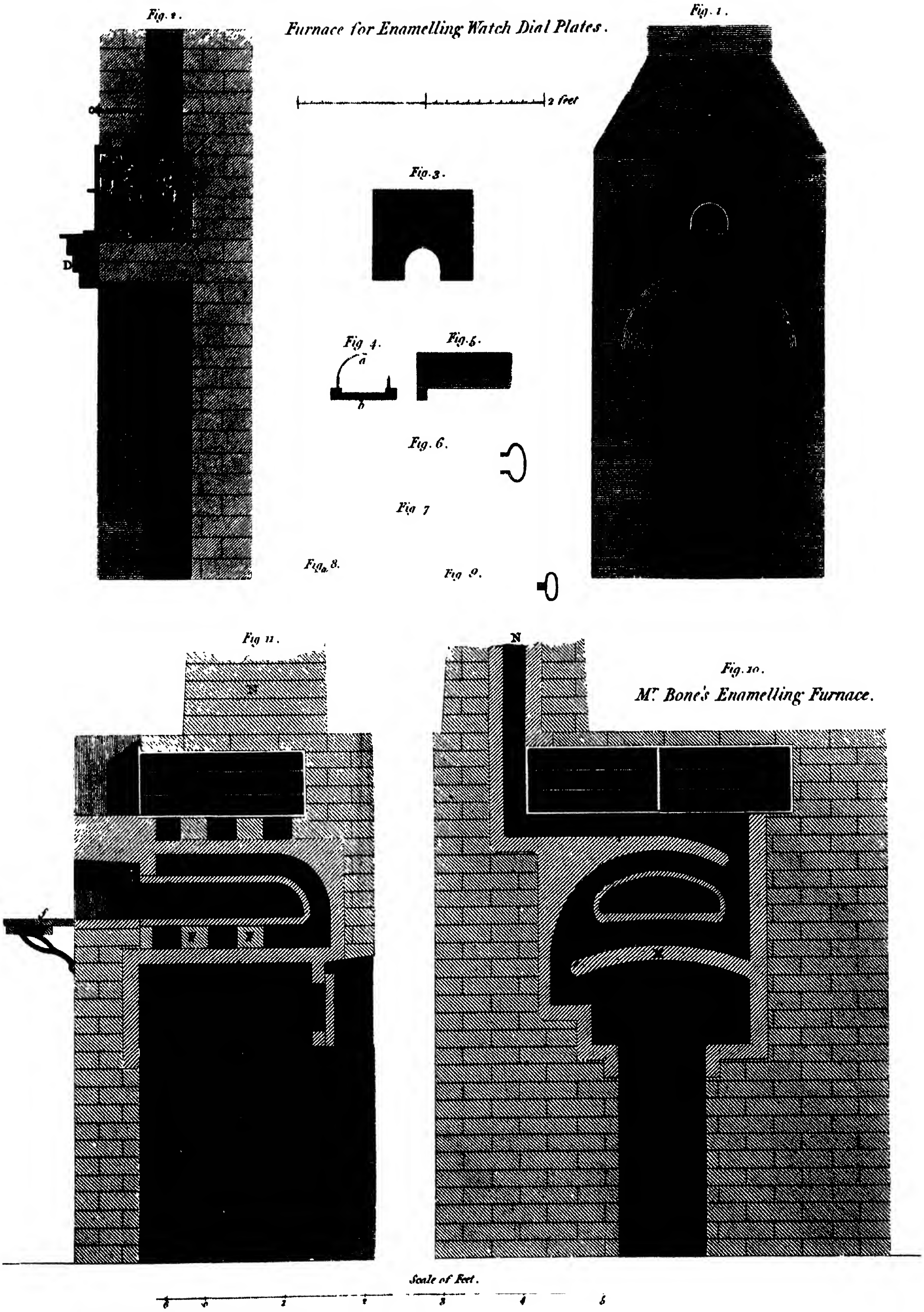
FURNACE.



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Fustian

FUSTIAN, in *Commerce*, a kind of cotton ſtuff, which ſeems, as it were, quilted, or whaled on one ſide.

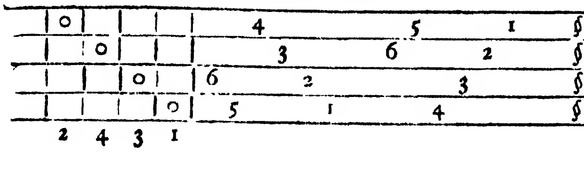
Manege derives the word from *fuſtanum*, which in the corrupt Latin writers is uſed in the ſame ſenſe, and is ſuppoſed to be formed from *fuſtis*, on account of the tree whereon the cotton grows. Bochart derives it from *fuſtat*, which, in Arabic, ſignifies the ancient city of Memphis, where cotton is produced in great abundance. Right fuſtians ſhould be made altogether of cotton thread, both woof and warp.

FUSTIAN, in the *Manufacture of Cloth*, is a ſpecies of coarſe thick twilled cotton, and is generally dyed of an olive, leaden, or other dark colour previouſly to its being uſed. Beſides the common fuſtian which is known by the name of pillow (probably pilaw) fuſtian, this manufacture, which is chiefly carried on in Lancaſhire, and the weſt riding of Yorkſhire, comprehends the cotton ſtuffs known by the names corduroy, velverett, velveteen, thickſett, and the other thick fabrics uſed for men's wearing apparel. The commoneſt kind of fuſtian is merely a twill of four, and ſometimes five leaves of a very cloſe ſtout fabric, and is very narrow, ſeldom exceeding 17 or 18 inches in breadth. It is cut from the loom in half pieces or ends as they are uſually called, and after undergoing the ſubſequent operations of dyeing, dreſſing, and folding is ready for the market. The end or half piece is generally from 30 to 40 yards.

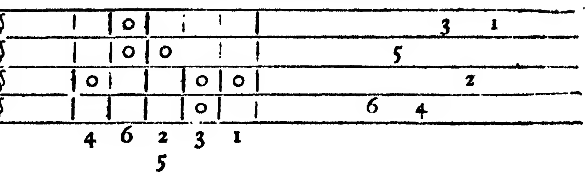
The draught and cording of common fuſtian is very ſimple, being generally a regular or unbroken tweel of four or five leaves. Below are ſpecimens of a few different kinds ſelected from thoſe moſt general in Lancaſhire.

The number of leaves of heddles are directed by the lines acroſs the paper, and the cording by the cyphers at the left hand corners, thoſe which raiſe every leaf being diſtinguiſhed by the cyphers, and thoſe which ſink them left blank, as more eſpecially explained in the article DRAUGHT and *Cording*.

No. 1.—Pillow Fuſtian.

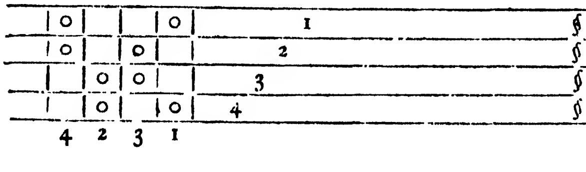


No. 2.—Plain Velveret.

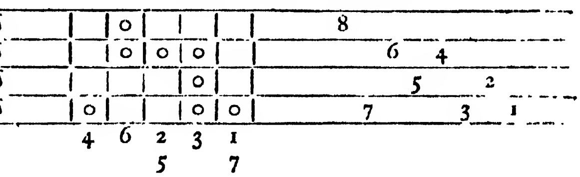


Of the above each contains four leaves of heddles or healds; that repreſented by No. 1. is wrought by four treddles, and that which is diſtinguiſhed by No. 2. by five; the ſucceſſion of inſerting the threads of warp into the heddles will be diſcovered by the figures between the lines and the order in which the treddles are to be ſucceſſivel preſſed down by the figures below.

No. 3.—Double Jean.

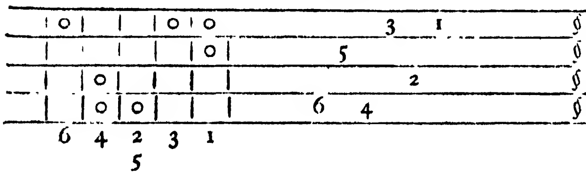


No. 4.—Plain Thickſett.

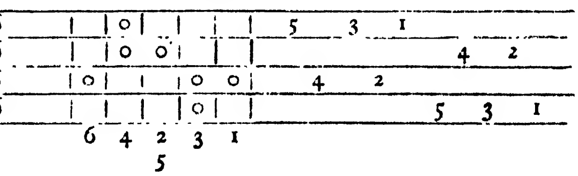


Theſe, like the former, are wrought with leaves. No. 3. requires four, and No. 4. five treddles. The ſucceſſion of inſerting the threads of warp, and of working the treddles, are marked by the reſpective numbers between and under the lines, as in the former example. Both are fabrics of clott in very general uſe and eſtimation as low priced articles.

No. 5.—Beſt Thickſett.

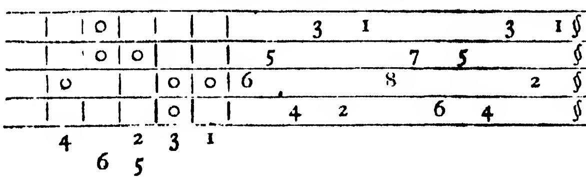


No. 6.—Velvet Tuſt.

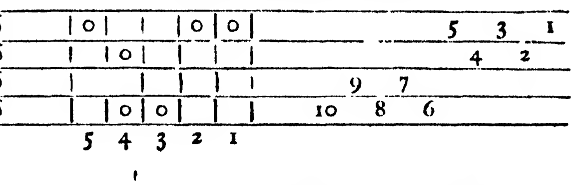


Theſe are further ſpecimens of what may be, and is, executed with four leaves, and in both examples five treddles are uſed. With two other ſpecimens we ſhall conclude our examples of this deſcription of work, and ſhall then add a very few ſpecimens of the more extenſive kinds.

No. 7.—Cord and Velveret.

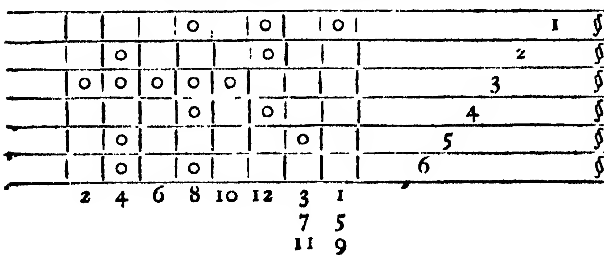


No. 8.—Thickſett Cord.

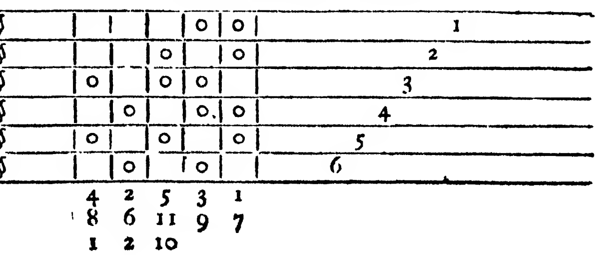


In theſe the ſucceſſion of drawing and working are marked like the former. The next are examples of patterns wrought with ſix leaves. No. 9. has eight, and No. 10. five heddles.

No. 9.—Double Corduroy.

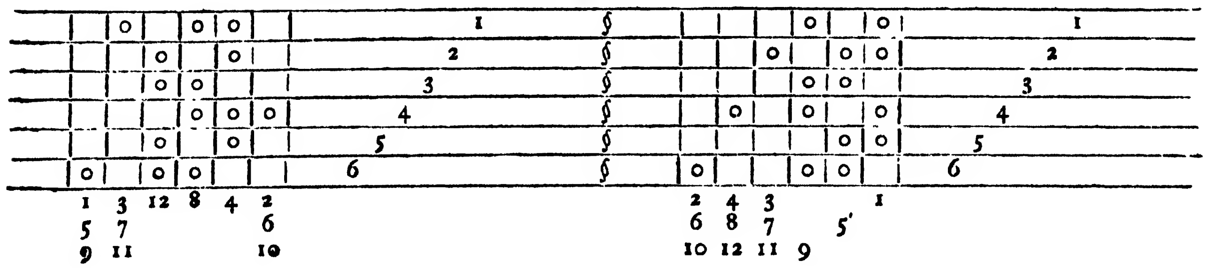


No. 10.—Genoa Thickſet.

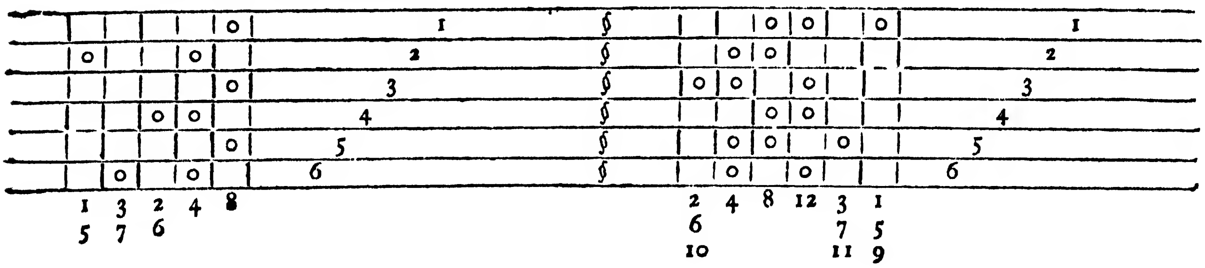


In both these the warp is inserted into the heddles the same way. The difference is entirely in the application of the cords and in the succession of pressing down the treddles. We now give four specimens of the species of flushed and cut work, known by the name of velveteen. They are also upon six leaves, and the difference is solely in the cording and in the treading.

No. 11. Queen's Velveteens. No. 12.

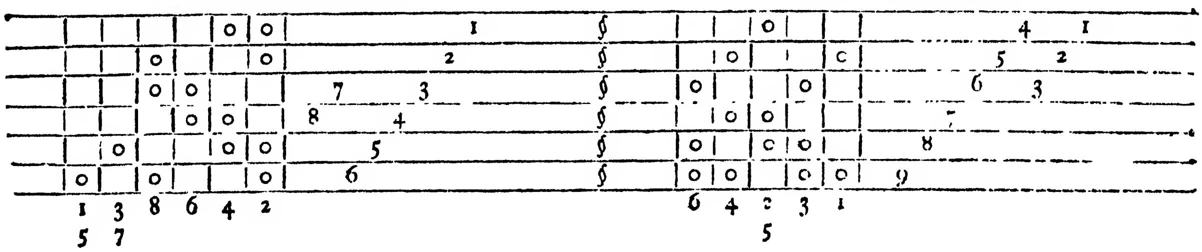


No. 13.—Plain Velveteen. No. 14.—Genoa Velveteen.

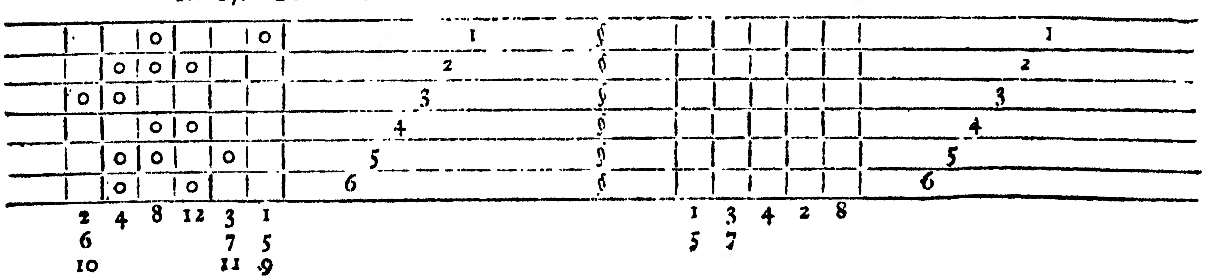


The additional varieties of figure which might be given are almost endless, but the limits of this article will not admit a further detail. Those already given are the articles in most general use. The varieties of fancy may be indulged to great extent, but it is universally found, that the most simple patterns in every department of ornamental weaving, are those which attract attention and command purchasers. We shall therefore only add two examples of king's cord or corduroy, two of Genoa and common velvet, and two more of jean. These will be found below.

No. 15.—King's Cord. No. 16.—Dutch Cord.



No 17.—Genoa Velvet. No. 18.—Plain Velvet.



Miſcellaneous Remarks.—In the manufacture of cloth it is difficult to fix upon any generic term for a variety of articles which, however, bear a very near analogy to each other, and are only diſtinguiſhable either by a difference in the material of which they conſiſt, or ſome ſmall variation in the proceſs of manufacture. In this article the word fuſtian has been uſed as the generic term, and examples have been given of the moſt common fabrics of the fanciful varieties of this article. Dr. Johnſon contents himſelf with deſcribing fuſtian merely as a kind of cotton cloth, which although probably very juſt, conveys no impreſſion whatever to the mind, excepting, that in its raw ſtate it is a vegetable ſubſtance, found in moſt of the tropical climates, and that when manufactured it ſerves as a covering for the human body, or for ſome other domeſtic purpoſe.

The examples, ſhort as the article is, will be found to contain an abſtract of moſt of the articles known by the various names of fuſtian, jean, corduroy, thickſet, velveret, velveteen, &c. in the cotton manufacture: of plaiding, blanketing, kerſeymere, plum ſerge, &c. in the woollen, and of ſatin, &c. in the ſilk. Of velvet there are properly only two kinds, that with a plain and that with a tweeled, or, as it is here called, a Genoa ground or back. When the material is ſilk, it is called velvet, when cotton, velveteen, and this is the ſole difference. In the ſame way a common tweeled cloth, when compoſed of ſilk, is called ſatin, when of cotton, fuſtian or jean, of woollen, plaiding, ſerge or kerſeymere, and in the linen is diſtinguiſhed by a variety of names according to the quality or fineneſs, or the place where the article is manufactured. It would tend greatly to ſimplify an analyſis of the various manufactures of cloth, were a general nomenclature introduced, as has been ſo ſucceſsfully done, in the more comprehenſive and important ſcience of chemiſtry, and the univerſal uſefulneſs of the art, as embracing a variety of articles of neceſſity to the poor, and of ornamental luxury to the rich, would render the attempt very deſireable in every reſpect. But while the knowledge of the art continues to be confined to operative mechanics and to manufacturers, little diſpoſed to ſtudy ſimplicity or arrange and claſſify ideas, this is rather to be wiſhed for than expected. In all the fanciful branches which form the ſubject of this article, the cloth undergoes a variety of proceſſes after coming out of the weaver's hands Of theſe, the firſt is cutting the fluſhed warp to raiſe the pile as it is called. This is performed on a flat table with a ſharp pointed knife. It is neceſſary in this to be careful that the knife may only cut the pile without injuring the back or fabric. I am not aware (ſays the writer of this article) that any attempt has ever been made to render this either more ſafe or ſpeedy by the aid of any kind of machinery. It is ſaid, indeed, that in the manufacture of Wilton carpets and hearth rugs, (which are merely worſted velvets,) grooved wires are introduced and cut out in the loom by the weaver, the groove in the wire ſerving as a guide for the knife, to prevent it from injuring the fabric of the cloth. The next operation is that of dyeing, which depending entirely on the chemical proceſſes neceſſary to give the greateſt poſſible brilliancy and durability of colour, to the material of which the cloth is compoſed, forms no part of this article. With little variation in the mechanical part, many kinds of cloth, differing widely in the material and equally ſo in the texture, are made: but the variety is boundleſs.

Fustian, in *Criticiſm*, a word uſed to expreſs bombaſt. See Bombast and Frigid.

FUSTIC, Old, as it is called in this country, (the *bois jaune* of the French,) is the wood of a large tree, the Morus *tinctoria*, which grows abundantly in many parts of the Weſt Indies and the American continent. It is of a ſulphur colour, pregnant with colouring matter, which is much more durable than any of the other yellow dyes, ſo that when applied without a mordant, the dye is conſiderably durable, but ſtill more ſo when uſed with the ſame mordants, as weld or quercitron. The decoction of fuſtic in water, when ſtrong, has a deep and ſomewhat dull red yellow, and by dilution becomes orange-yellow. Acids produce in it only a ſlight precipitate, which alkalies rediſſolve, rendering the liquor red. Fuſtic, though valuable on account of the durability of its colour, is ſeldom uſed for the pure yellows, as the colour given by it is dull and muddy. It is chiefly uſed in compound colours, as in forming green with a Saxon-blue baſis; or in producing, with a mixed mordant of alum and iron-liquor, an infinite variety of drab and olive dyes, in which caſe the dullneſs of its colour is of no conſequence. It is chiefly uſed in general dyeing, and ſeldom in printing. It goes much farther than weld.

Young fuſtic, the *fuſtet* of the French dyers, *Rhus cotinus*, or Venice ſumach, is a ſhrub growing in Italy, and the ſouth of France, which gives a fine greeniſh yellow without any permanence, ſo that it is never uſed alone, but merely as an acceſſory colour to heighten cochineal and other dyes, and occaſion their approach to yellow.

Gage, in *Carpentry* and *Joinery*, is an inftrument for drawing a line on one of the faces of a piece of ftuff parallel to another, in order to reduce the ftuff to a breadth or thicknefs.

Its chief ufe is for gaging of tenons true, to fit into mortiffes; and for gaging ftuff of an equal thicknefs.

It is made of an oval piece of wood, fitted upon a fquare ftick, to flide up and down ftiffly thereon, and with a tooth at the end of a ftaff, to fcore, to ftrike a line upon the ftaff at any diftance, according to the diftance of the oval from it.

Gage, in the *Sea Language*. When one fhip is to windward of another, fhe is faid to have the *weather gage* of her.

The feamen alfo call trying how much water a fhip draws *gaging*, or rather *gauging* of her; and it is done thus: They drive a nail into a pike, near the end, and then put down this pike by the rudder, till the nail catch hold under it; for then, as many feet as the pike is under water is the fhip's gage, or depth of water fhe draws.

Gage, among *Letter-founders*, is a piece of box, or other hard wood, varioufly notched; which is ufed to adjuft the dimenfions, flopes, &c. of the different forts of letters. There are feveral kinds of thefe gages. See Foundery.

Gage, in *Pneumatics*, is of various forts, according to the purpofes to which it is applied. Thus.

Gage *of the Air-pump*. The principle upon which the gage of the air-pump is conftructed is very obvious; we fhall here briefly defcribe thofe that are in common ufe, and refer to the article Air-*pump* for the mode of their application. The "fhort barometer gage" is merely the lower part of a barometer or a tube about eight or nine inches in length, filled with mercury, and immerfed with its aperture into a fmall quantity of mercury contained in a glafs-veffel, which forms the ciftern. This gage is either placed under the receiver upon the principal plate of the pump, or it is placed under a feparate fmall receiver, upon a fmall auxiliary plate, which is annexed to fome air-pumps for this purpofe. As this gage is not equal to a whole barometer, it will not fhew the very fmall degree of rarefaction; but its indications will commence when about three-quarters of the air have been removed from the receiver, that is, when the air has been rarefied till its remaining elafticity is not able to fupport that column of mercury. This gage has a fcale of inches and parts of an inch affixed to the tube, which fhews the precife altitude of the mercury in it. The "long barometer gage" is a tube of about thirty-three inches in length, open at both ends, having its lower end immerfed in a ciftern of quickfilver, which is fixed on the pedeftal, or lower part of the frame of the pump; the tube itfelf reaching from that place to the height of the plate. The upper aperture of the tube communicates, by means of a brafs tube, with the infide of the pump. This is, in reality, an empty barometer, which is filled with quickfilver, by withdrawing the air from it through its upper aperture; and if the pump could produce a perfect vacuum, the mercury in this long gage would rife as high as it does in the common barometer; but as the pump cannot exhauft fo far, therefore the difference of altitude between the mercury of the long gage, and that of a common barometer, fhews the quantity of air that remains in the receiver. This difference of altitude is indicated by a fcale of inches and parts of inches, which is always affixed to the long barometer gage. As the altitude of the mercury in a common barometer is to its cotemporaneous altitude in this gage, fo is the whole quantity of air which was in the receiver before the rarefaction to that quantity which has been drawn out of it. The "fyphon-gage" differs from the fhort barometer gage merely in this circumftance; that inftead of terminating in a little ciftern, in this gage the tube is bent and rifes upwards with its aperture, which by means of a brafs tube is made to communicate with the infide of the pump; fo that the afcending leg of the tube performs the office of a ciftern: hence, in rarefying the air, the mercury defcends from the clofed end of the tube, and rifes into the afcending leg; and confequently the altitude of it in one leg above its altitude in the other leg, which is in reality the ciftern, fhews the degree of rarefaction, and this altitude is denoted by an annexed fcale of inches and parts of inches.

The gages above-mentioned evidently indicate the elafticity of the fluid, which remains in the receiver of the pump after a certain degree of rarefaction; and it is immaterial whether that elaftic fluid be air, or vapour of water, or other elaftic fluid; but there is another gage, which from its fhape was called the "pear-gage" by its inventor, Mr. Smeaton, and which fhews (not at the actual time, but after the re-admiffion of air into the receiver) how much air was left in the receiver in the preceding rarefaction. This pear-gage confifts of a glafs-veffel A (*Plate* XIV. *Pneumatics*, *fig.* 4.) which has a fmall projecting orifice B, and at the other end it is extended into a tube clofed at D; the capacity of this tube is the 100dth part of the capacity of the whole veffel. This gage is fufpended, with its aperture downwards, to the lower end of a flip-wire, or a wire which paffes through a collar of leather, within a glafs-receiver of the pump, and exactly under it a fmall cup, containing quickfilver, is placed upon the plate of the pump. When the pump has been worked to the intended degree, the air in the pear-gage is evidently rarefied as much as it is in the receiver. In that ftate, by lowering the flip wire, the pear-gage is let down till its aperture B has reached the bottom of the mercury. This done, the external air is admitted into the receiver; but it cannot be admitted into the pear-gage, becaufe the aperture B of that gage is now immerfed in the quickfilver; but the preffure of the atmofphere on the furface of the quickfilver forces that fluid into the pear-gage, and fills it up to a certain degree E; then the upper part D E of the gage will contain all the air or vapour which occupied the whole cavity of the gage during the rarefaction. Annexed to the upper part D E of the gage is a divided fcale, which fhews what part of the capacity of the whole gage is filled with air, and of courfe it manifefts the degree to which the rarefaction of the air had been carried. *E. G.* If we find that the part D E of the gage, which is filled with air above the quickfilver, is the 500dth part of the whole, we may conclude, that the air in the receiver had been rarefied 500 times, &c. But between the indications of this and of the preceding gages, there

will be a very confiderable difference. When the receiver contains no other fluid befides air, then the pear-gage and the other gages indicate the fame degree of rarefaction; but if the receiver contain the vapour of water or of other liquor, then the pear-gage will indicate a much greater degree of rarefaction than the other gages; becaufe the vapour which has elafticity fufficient to fupply the place of air in the receiver, on the re-admiffion of air, is condenfed into a fpace much fmaller than the fame quantity of rarefied air can be condenfed into; fo that the pear-gage fhews the quantity of *air* alone which had been left in the receiver; whereas the other gages fhew the quantity of elaftic fluid which is actually remaining in the receiver.

The extraordinary powers of exhauftion in Mr. Smeaton's air-pump, as they are indicated by his pear-gage, have been confidered with peculiar attention by Mr. Nairne, F.R.S. He was led to profecute a feries of experiments on this fubject, by obferving the remarkable difference between the indications of exhauftion and rarefaction by this gage, and by the common barometer-gage. Having ufed every poffible precaution in preparing his different gages, he neverthelefs found, that, when they are put under a receiver, placed on a leather dreffed in alum, and foaked in oil and tallow, according to his ufual method, and the pump was worked for ten minutes, the quickfilver in the barometer-gage rofe to within one tenth of an inch of the height of the quickfilver in the ftandard barometer, which was at that time at thirty inches, and indicated that the air had been rarefied only about three hundred times; whereas Mr. Smeaton's pear-gage indicated a degree of exhauftion equal to fix thoufand times; the whole of its cavity, on dipping its open end into the cup of quickfilver, and letting in the air, except a fix thoufandth part, being filled by the quickfilver. The difference of indications by thefe two gages was found much more confiderable in fubfequent experiments. Having an opportunity of repeating fome of thefe experiments before the honourable Henry Cavendifh, Mr. Smeaton, and others, in April 1776, Mr. Cavendifh accounted for the obferved and aftonifhing difference, by referring to fome experiments of his father, lord Charles Cavendifh, from which it appeared, that water, whenever the preffure of the atmofphere on it is diminifhed to a certain degree, is immediately turned into vapour, and reduced as fuddenly to water again on reftoring the preffure: the degree of preffure varies according to the temperature of the water; for when the heat is 72 of Fahrenheit's fcale, it turns into vapour as foon as the preffure is reduced to that of three quarters of an inch of quickfilver, or about one fortieth of the ufual preffure of the atmofphere; but when the heat is only 41, the preffure muft be reduced to that of a quarter of an inch of quickfilver, or to one hundred and twentieth of the ufual preffure, before the water turns into vapour. According to this theory, whenever the air in the receiver is exhaufted to the abovementioned degree, the moifture adhering to the different parts of the machine will be converted into an elaftic vapour, and fupply the place of the air, which is drawn away by the working of the pump; and the fluid left in the receiver and pear-gage will be chiefly this vapour. When the air is let into the receiver, the vapour within the pear-gage will be reduced to water, and only the real air will remain uncondenfed; and therefore this gage only fhews how much real air is left in the receiver, and not how much the preffure or fpring of the included air is diminifhed; whereas the barometer-gage fhews how much the included fluid is diminifhed, and that equally, whether it confifts of air or vapour. In order to afcertain the truth of this plaufible theory, Mr. Nairne proceeded to free every part of his apparatus as much as poffible from any adhering moifture, concluding that by this means he fhould be able to bring the two gages to an agreement. Inftead of placing the receiver on leather, as before, he put it on the pump-plate, made as clean and dry as poffible, and applied a cement round its edge to exclude the outward air. When the pump in this ftate was worked for ten minutes, the barometer-gage indicated a degree of exhauftion nearly equal to fix hundred; and, on letting the air into the receiver, the pear-gage indicated a degree of exhauftion little more than fix hundred alfo. In another experiment he put a piece of the oiled leather above mentioned in the receiver, and found, on working the pump, that the barometer-gage indicated a degree of exhauftion of nearly three hundred, but the pear-gage indicated a degree of exhauftion not lefs than four thoufand. But on taking out the piece of leather, and repeating the experiments, the two gages agreed, as before. Having thus concluded, in general, that a confiderable quantity of vapour arofe from the compound of leather, alum, oil, and tallow, it was his next object to find out from which of thefe fubftances the vapour was principally derived. For this purpofe he feparately and fucceffively included in the receiver two ounces of tallow, the fame quantity of oil and alum, and a piece of leather as it comes from the leather-fellers, weighing a hundred grains: from thefe experiments he found that the elaftic vapour, which occafioned fo great a difference in the teftimony of the gages, arofe chiefly from the leather, and very little from the tallow, oil, and alum. In the experiment with the leather, it fupplied the place of the exhaufted air fo faft, that he could not in ten minutes make the barometer-gage indicate a degree of exhauftion of more than a hundred and fifty-nine; whereas that of the pear-gage was a hundred thoufand. In order to determine whether the difference in the gages was occafioned by the moifture of the leather, Mr. Nairne repeated the experiment with a piece of frefh leather, weighing a hundred grains. The pear-gage indicated a rarefaction of a hundred thoufand, and the leather had loft two grains of its weight; when the fame piece of leather was fo thoroughly dried by the fire till it would lofe no more of its weight, and thus reduced to eighty grains, it gained two grains in the experiment, and the pear-gage exhibited a rarefaction only of two hundred and eighty. The leather was afterwards held in the fteam of hot water till it had regained its former moifture and weight, and the degree of exhauftion indicated by the pear-gage was a hundred thoufand, and the lofs of weight, two grains, as before. In the firft of thefe experiments, the degree of rarefaction indicated by the barometer-gage was a hundred and thirty-four; in the fecond, two hundred and fixty-eight; and in the third, one hundred and forty-feven. The effect of the vapour arifing from fmall quantities of different fluids, and from other fubftances containing moifture, was tried in a variety of inftances; and having found that the fmall quantity of moifture which exhaled from the fubftances under the receiver, prevented the pump from exhaufting to a confiderable degree, Mr. Nairne fufpected that whenever wet leather had been ufed to connect the receiver with the plate, there muft have arifen fo great a quantity of vapour as to have prevented the degree of exhauftion from being near fo great as in other inftances. This led him to another fet of experiments, in order to afcertain this fact. Having firft placed the receiver on the pump-plate, made clean and dry, with only a little oil poured round the outfide edge of it, both gages agreed in indicating a rarefaction of fix hundred, as before: but when the receiver was fet on leather that had been foaked for two days in water, the rarefaction indicated by the barometer-gage

was uniformly fifty-one in three different trials; but the pear-gage exhibited first sixteen thousand, in the second instance fifteen hundred, and in the third one thousand: when the receiver was placed on a piece of leather, soaked in a mixture of water and spirit of wine, the barometer-gage in three trials always indicated a degree of exhaustion equal to forty-seven; but the pear-gage was unaccountably various; in the first trial being twelve thousand, in the second, eleven hundred and fifty; and in the third, five hundred. By these experiments it sufficiently appears, that the use of leather soaked in water, or in water and spirit of wine, prevents the pump from exhausting to any considerable degree. By two other experiments, in which water was used for softening the leathers of the pistons of a common air-pump, we find that the highest degree of rarefaction that could be procured was thirty-seven, according to the barometer-gage; and thirty-eight according to the pear-gage. Mr. Nairne's last experiment furnishes a very extraordinary evidence of the effect of vapour on the barometer-gage: having put a phial of ether under the receiver, in order to produce artificial cold, and working the pump for half an hour, the degree of exhaustion indicated by the barometer-gage was only sixteen; though the same pump exhausted above four hundred times before the ether was put under the receiver. The degree of cold produced by means of ether, in the exhausted receiver, was 48°, below 0 in Fahrenheit's scale, or 103 below 55, which was the temperature of the air in the room where the experiment was made. Phil. Transact. vol. lxvii. part ii. art. 32, page 614, &c.

GAGE *of the Barometer*, is a contrivance for estimating the exact degree of the rise and fall of the mercury in the Torricellian tube. It is well known, that whilst the mercury rises in the tube, it sinks in the cistern, and *vice versâ*; and, as the distance between the divisions graduated on the annexed scale and the surface of the mercury in the cistern is not truly shewn by the numbers on the scale, errors must happen in determining the precise height of the mercury. To remedy this inconvenience, a line is cut upon a round piece of ivory, which is fixed near the cistern: this line is accurately placed at a given distance from the scale; *e. gr.* twenty-seven inches; and a small float of cork, with a cylindric piece of ivory fixed to its upper surface, on which a line must be cut at the distance of two inches, exactly from the under surface of the cork, is left to play freely on the quicksilver, and the cylinder works in a groove made in the other piece: from this construction it appears, that if these marks are made to coincide, by raising or lowering the screw which acts on the quicksilver, then the divisions on the scale will express the true measure of the distance from the surface.

GAGE *of the Condenser*, is a glass tube of a particular construction, adapted to the condensing engine, and designed to shew the exact density and quantity of the air contained at any time in the *condenser*, which see. For this purpose, let *D d e f c*, *Plate* XIV. *Pneumatics*, *fig.* 5. be a small glass tube, about one-tenth of an inch in diameter, open at D, but hermetically sealed at *c*; D E a larger tube, hermetically sealed at D, and containing at that end a quantity of mercury, which takes up two or three inches in length, and covers the open end of the smaller tube; the other end C, of the larger tube, is strongly cemented into the brass elbow-piece O E *o* at C, *fig.* 6, so as not to be quite at right angles with O *o*, but to incline a little downwards, that the mercury at D may not run towards C, and pass into the condensing glass G B. This gage is screwed on at *o*, and the injecting syringe at O, a cock being interposed at O or *c*, or not used at all, according to the nature of the experiment. Whilst air is injected into the condensing glass, and the large tube of the gage at the same time, the air in the smaller tube, which has no communication with the injected air, must be rarer and weaker, and, therefore, the mercury at D will enter the tube, and advance in it, in proportion to the condensation of the air in G B. In *fig.* 5, *d*, *e*, *f*, represent three rings of springy wire, at such distances as to shew, by the motion of the mercury in the small tube, when the density of the air is doubled, tripled, or quadrupled; because the air, which at first filled the whole small tube, now takes up only the spaces *c d*, *c e*, *c f*; or, in Mr. Hawksbee's style, one, two, or three atmospheres are thrown in.

Another kind of gage may be put within the condensing glass, at the bottom of it, when the use of the preceding gage would be inconvenient. This is a short cylinder of wood, *fig.* 7, about an inch thick, with a hole through its middle between *a* and *b*, of about 1½ inch in diameter; the outward diameter of the cylinder must be about four inches, so that the cylinder may easily stand within the condensing glass on the plate, supporting its bottom at B, *fig.* 6. There is a hole at A of about ¼ of an inch in diameter, and ¾ of an inch deep, filled with mercury; *a c d b* is a small glass tube, open at *a*, but hermetically sealed at *b*, and bent to a right angle at *c*, the middle of the distance between *a* and *b*. When the open end, *a*, is immersed in mercury, and the air on the surface of the mercury condensed, the air in the tube will recede towards the elbow *c*, and the mercury following it, shew to what degree it is condensed. When the mercury is at *c*, then one additional atmosphere bears upon its surface, and two atmospheres, if it be come to *d*; which places are marked by rings of springing brass wire; at *a* and *b*, about an inch of the ends of the tube are bent to a right angle, that the end *b* may go into the wood, whilst the end *a* goes under the surface of the mercury, where it is held by a cork, whilst air is injected into the condensing glass. Desaguliers' Exp. Phil. vol. ii. p. 394, &c.

Gallic Acid

GALLIC Acid. *Acide Gallique*, Fr. *Galluſſaure, Gallapfelſaure*, Germ.—The infuſion of nut-galls had long attracted the attention of chemiſts, and had been the ſubject of numerous experiments before it was proved to contain a peculiar acid. Dr. Lewis, when engaged in an enquiry on the beſt method of making ink, found that the precipitate which a ſolution of galls affords with ſulphat of iron is not attracted by the magnet; he likewiſe obſerved that the black colour which it imparts to the acid ſolutions of iron is capable of being deſtroyed and re-produced by the alternate application of alkalies and acids. The academicians of Dijon went farther; they aſcertained that it reddened vegetable blues, diſſolved iron, decompoſed the alkaline hydro-ſulphurets, produced with metallic ſolutions various coloured precipitates, and, that when diſtilled, the fluid product had the ſame properties as the original ſolution; but it was reſerved for Scheele to ſeparate the acid from the ſubſtances with which they had examined it, in combination. This he in a great meaſure effected by the proceſs which he made public in 1780. The acid diſcovered by the Swediſh chemiſts, when its peculiar nature was determined, acquired, on account of the ſubſtance which firſt afforded it, the name of acid of galls, or gallic acid. But it is not confined alone to nut-galls; a variety of other aſtringent vegetables are capable of affording it.

The following method of obtaining the acid, is that diſcovered by Scheele. Make an infuſion, by macerating one part of gall-nuts, reduced to a coarſe powder, in ſix parts of cold water. At the end of fifteen days filter the ſolution, and place it in a large veſſel, covered with a ſheet of paper, in a warm room. In a ſhort time, a mouldy pellicle will appear on the ſurface of the liquid, which is to be occaſionally broken: as the operation proceeds, the original aſtringent taſte diminiſhes, and the acid taſte becomes more ſenſible. At the end of two or three months, the interior of the veſſel will be found coated with a brown matter, containing diſperſed, ſhining, granular, cryſtals. Separate this ſediment, and cover it with rectified alcohol; gently heat the mixture, and a ſolution of the cryſtallized acid in alcohol will be formed, which, evaporated, affords gallic acid in the form of very fine grains.

Scheele diſcovered that gallic acid is volatilized by a low degree of heat; and, in diſtilling nut-galls, he found the acid ſublimed and condenſed in the receiver. Mr. Deyeux was the firſt to avail himſelf of this property, in order to obtain the acid free from the tannin and extractive matter, which it always contains, when prepared in the old way. He gradually heated powdered nut-galls in a large glaſs retort, till a ſublimate aroſe, which condenſed in brilliant white cryſtalline plates. An increaſe of heat occaſions the decompoſition of the acid; and if the operation is long continued an oil diſtils over that diſſolves the acid ſublimate, and renders the experiment fruitleſs. This method, without great precaution, is very liable to fail. Mr. Davy recommends ſeparating previouſly ſome of the tannin of the nut-galls, by infuſing them, for a ſhort time, in a little water, by which means the production of empyreumatic oil is diminiſhed. The ſame chemiſt obſerves, that it is time to ſtop the operation, when the cryſtals formed in the lower part of the retort begin to melt. But, even allowing all theſe precautions are obſerved, it appears almoſt impoſſible to obtain the acid entirely free from empyreumatic oil, the preſence of which is indicated from the very commencement of the operation, by the peculiar aromatic ſmell that is produced.

A variety of other methods have been propoſed for pro-

curing the acid in a ſtate of purity. It will be ſufficient to mention briefly thoſe which appear moſt adequate to the purpoſe. Mr. Davy's method: Boil carbonat of barytes in an infuſion of galls; gradually add dilute ſulphuric acid to the bluiſh-green liquid which is thus produced, till all the barytes is ſeparated: the liquid, on the application of the common teſts, appears to be perfectly free from tannin and extractive matter; evaporate it to dryneſs, and the gallic acid will be obtained This method is far preferable to the one recommended by Mr. Fiedler, which conſiſts in digeſting alumine with a ſolution of galls, decanting the clear liquor, and ſeparating the cryſtals of gallic acid, (more probably of ſuper-gallat of alumine.) which are produced by ſlow evaporation. Mr. Richter's method: Take any quantity of gall-nuts reduced to a fine powder; digeſt them in cold water; agitate the mixture; paſs the liquid through a cloth; add more water to the reſidual pulp; and ſeparate the water by means of a preſs: join the liquors, and ſlowly evaporate them; a brittle dark coloured ſubſtance remains. Cover this ſubſtance, reduced to a fine powder, with alcohol, and a ſolution of a pale ſtraw-colour is formed; a ſecond infuſion of alcohol acquires but very little colour. Diſtil the two extracts together in a ſmall glaſs retort to one-eighth; add water to the reſidue, and expoſe it to a gentle heat; evaporate the ſolution thus formed, and very ſmall white priſmatic cryſtals of gallic acid will appear. By this proceſs, half an ounce of cryſtals may be procured from a pound of gall-nuts. M. Bouillon La Grange, who has employed it, ſays, he was never able to obtain acid of the purity deſcribed by Mr. Richter. The cryſtals he procured were always of a light ſtraw-colour; and he found that repea ed diſtillations with alcohol did not render them white, the gallic acid itſelf being partially decompoſed by this treatment. One objection to this method is, that unleſs the alcohol is highly rectified it diſſolves a portion of tannin.

The properties of gallic acid appear, in ſome meaſure, to depend on the method employed for its production. The different methods, generally conſidered, are of two kinds, the dry and the moiſt. Accordingly, there appear two varieties of gallic acid, that procured by diſtillation differing conſiderably from that formed by cryſtallization, if any credit is to be attached to the obſervations of M. Bouillon La Grange.

Gallic acid, procured in the moiſt way, is of a light ſtraw-colour; it has a ſharp acid taſte, but poſſeſſes leſs aſtringency than nut-galls; it changes vegetable blues to red. For its ſolution, it requires 12 parts of cold water, or 1½ of boiling; and it imparts to this liquid a light lemon-colour, which becomes black by expoſure to the air. Alcohol takes up, when cold, about ¼th of its weight of this acid; but at a boiling temperature, nearly its own weight. It is ſoluble in either. Expoſed to heat, it readily fuſes; it forms juſt before it begins to ſublime a brown viſcid fluid; full of air-bubbles; and emits vapours which have an odorous ſmell. The action of a ſtrong heat partially decompoſes it; but to accompliſh this completely, it requires, on account of its volatility, to be ſubjected to repeated diſtillations, and the products appear to vary according to the intenſity of the heat applied. Scheele procured, by diſtilling it in a glaſs retort, firſt, an acid liquor, free from oil; next, part of the acid itſelf, which, condenſed in the liquid, forms and ſhoots into cryſtals, as it gradually cools, and a large reſidue of charcoal. M. Deyeux has found that it is capable of being conver ed by heat into oxygen and charcoal. From whence he concluded that it differs only from carbonic acid in containing leſs oxygen; but his reaſoning is fallacious, from his not having taken into conſideration the acid fluid that is alſo produced. On the contrary, M. Bouillon La Grange obtained, by its diſtillation, an acidulous liquid, charcoal, and much carbonic acid gas, with which was mixed a little carburetted hydrogen gas. The latter gas was ſo concealed by the former, that it did not appear inflammable till the carbonic acid gas was ſeparated by means of lime-water.

Gallic acid is decompoſed and carbonized by ſtrong ſulphuric acid; the ſame effect, moſt probably, is produced by liquid fluoric acid; nitric acid converts it partly into the malic and oxalic acids; oxymuriatic acid, according to M. Bouillon La Grange, has no action on it; it is ſoluble in the other acids without decompoſition.

With the earths and alkalies it combines, forming ſalts, denominated gallats, of which very little is known. The alkaline gallats poſſeſs a conſiderable degree of ſolubility: according to Richter they give black precipitates, with the ſalts of iron, and precipitate all other metallic ſolutions. From the obſervations of Mr. Davy, the alkaline earths appear capable of combining with two different proportions of this acid, an exceſs of acid rendering the ſalts very ſoluble, which before poſſeſſed little ſolubility. Gallic acid precipitates glycine, yttria, and zircon from their acid ſolutions, and decompoſes all the carbonats.

The gallats are decompoſed by a ſtrong heat. Some of them have been found to yield acetic acid when diſtilled with very dilute ſulphuric acid.

The action of gallic acid on metallic ſalts appears to be proportionable to the ſtrength of the affinity which the different metals have for oxygen. The ſolution of this acid imparts to a ſolution of gold a dark green colour, and produces a brown precipitate, which is metallic gold. It renders a ſolution of ſilver brown, and occaſions, with the aſſiſtance of a gentle heat, the depoſition of a grey powder, which is finely divided ſilver. The precipitate which it gives with a ſolution of mercury is orange yellow; with a ſolution of copper, brown; with a ſolution of acetat of lead, white; and with biſmuth, lemon coloured. It imparts to molybdic acid a dark yellow, without occaſioning any precipitate. It appears to have no effect on the ſalts of platina, zinc, tin, cobalt, and mangancſe. When boiled on red oxyd of mercury, the acid itſelf is decompoſed, and running mercury is produced. It ſuffers the ſame change when ſimilarly treated with the black oxyd of manganeſe or oxyd of tin; but theſe metals, inſtead of being reduced, are brought only into lower ſtates of oxydation. The moſt diſtinguiſhing property this acid poſſeſſes, is that of giving dark-blue coloured precipitates with the oxygenated ſalts of iron. According to M. Berthollet's views of the ſubject, it is not abſolutely neceſſary that the iron ſhould be at the maximum of oxydation for this effect to be produced, for he obſerves that the ſalts which contain the oxyd at the minimum, though not changed at firſt by gallic acid, yet become coloured; when the ſolution confined from air is much diluted with water. He conceives, and M. Richter is of the ſame opinion, that every thing which weakens the affinity of the ſulphuric acid for the oxyd promotes the combination of the gallic acid with the metal in whatever ſtate of oxydation it may be: indeed the latter chemiſt aſſerts, that a ſolution of green ſulphat of iron is never coloured by gallic acid, unleſs tannin be preſent, which, according to him, attracts the ſulphuric acid, and then the gallic acid unites with the oxyd of iron ſeparated. Mr. Prouſt, from his obſervations, has been led to a different concluſion. He thinks that iron is incapable of combining with gallic acid, unleſs highly oxydated; and he thus explains the colour which a mixture of green ſulphat of iron and gallic acid acquires by expoſure to the air; the blackening of ink after being poured out of cloſe

veſſels, and many of the manipulations of dyers who find their profit in this oxydating proceſs carried on in the atmoſphere. M. Berthollet indeed admits that gallic acid ſtrikes a deeper colour with the oxygenated ſalts of iron, than with thoſe which contain leſs oxygen; but he attributes this effect to the decompoſition of the acid itſelf, and the developement of ſome of its charcoal.

Such are the general properties of gallic acid procured in the moiſt way. M Bouillon La Grange has pointed out a few inſtances in which the acid obtained by ſublimation according to the method of Deyeux differs. Theſe differences it will be neceſſary to mention, they are principally the following. The ſublimed acid is leſs acid to the taſte. It gives to metallic ſolutions precipitates of different colours. Its ſolution is darkened by oxymuriatic acid. It imparts variable colours to ſulphat of iron, and it does not precipitate gelatine. It moreover appears to contain a little eſſential oil, which by diſſolving the acid in water, ether, or a ſtrong ſolution of pot-aſh, ſeparates, becomes ſenſible to the ſmell, and is ſeen ſwimming on the ſurface of the fluid.

The nature of gallic acid is not yet ſatisfactorily determined. The generally received opinion is, that it is a ſimple acid, but there are ſome chemiſts who maintain it to be a compound one; M. Bouillon La Grange has endeavoured to ſhew that the cryſtallized acid procured in the moiſt way is compoſed of acetic acid, tannin, and extractive, and that the acid obtained by ſublimation is merely acetic acid modified by a peculiar eſſential oil. His arguments for this opinion are, the difficulty, indeed the impoſſibility, of obtaining the acid free from theſe impurities, and the production of acetic acid by the diſtillation of gall-nuts with water, and alſo by ſubmitting ſome of the gallats to the ſame operation with dilute ſulphuric acid. However ingenious this reaſoning may be, it is not concluſive. Doubt can be alone baniſhed from the ſubject, by ſubmitting the theory to the teſt of experiment; by endeavouring to form gallic acid of either kind by adding to the acetic the ſubſtances by which it is ſuppoſed to be modified, in the acid in queſtion. It is certain, however, that, like the other vegetable acids, gallic acid is a compound of carbon, hydrogen, and oxygen, and not, as M. Deyeux maintains, of carbon and oxygen alone.

Its uſes are few, in its pureſt ſtate, and theſe are known alone in the laboratory of the chemiſt; but in combination with other ſubſtances, it is of extenſive and important applications in the arts. See the articles DYEING and INK.

Elemens de Chimie, tom. iii. Crell's Chemical Journal, vol. i. p. 24. Journals of the Royal Inſtitution, vol. i. p. 274. Nicholſon's Journal, 8vo. vol. i. p. 458. Phil. Mag. vol. xxiii. p. 74. Annales de Chimie, tom. xvii. Chemical Statics, vol. ii. Annales de Chimie, tom. 60. p. 156.

Gas Light

GAS *Light, Apparatus for producing.* The light and heat procured by the combuftion of carburetted hydrogen gas, is one of thofe recent inventions which promifes to be of the moft general utility, though it may be faid to be at prefent in its infancy; the inflammability of the gas, produced from the diftillation of pit coal, has long been a fact familiar to chemifts, though it is only within thefe few years that experiments have been made, with a view to determine the beft form of an apparatus for producing the gas, at the leaft expence of fuel for the diftillation, and at the fame time to feparate from it the tar and ammoniacal fluid which are thrown out from the coals with it; and would, if fuffered to remain with the gas, caufe many inconveniences from their intolerably offenfive fmell, but may, when feparated, be applied to ufeful purpofes.

Mr. Murdoch was probably the firft perfon who put in practice gas lights on an extenfive fcale; he commenced his experiments on this fubject in the year 1792, and in 1798 he applied it for the lighting part of the very extenfive manufactory of Meffrs. Boulton, Watt, and Co. at Soho near Birmingham, and in 1802, at the time of the Peace, the illumination of the Soho works was made by gas. Since this period, the method has been adopted in many places by different individuals, who, proceeding from their own ideas, naturally introduced various forms of the apparatus, the moft perfect of which we propofe to defcribe with drawings, in fuch a manner as to enable mechanics to conftruct them, this being the moft probable means of their being farther improved, and their advantages more fully eftablifhed. The carburetted hydrogen gas is produced in the following manner: A quantity of pit coal is introduced, and clofed up in an iron retort, difpofed in a proper furnace, by which it can be heated fo as to throw out the volatile portions of the coals; thefe are conducted by a pipe into a refrigeratory, where the tar and ammoniacal fluid are depofited: the gas then enters into a gazometer, being in its way paffed through water to wafh and take from it any remaining tar or other impurities which may caufe an unpleafant fmell. The gazometer is fitted up in the fame manner as for other chemical experiments, rifing and falling freely in water to regulate the admiffion of the gas, which is conveyed by pipes from it to the burners or lamps where it is confumed. Thefe are formed in various ways, either a tube ending with a fimple orifice, at which the gas iffues in a ftream; and if once lighted will continue to burn with the moft fteady and regular light imaginable, as long as the gas is fupplied. At other times a number of very minute holes are made in the end of a pipe, which form as many *jets de feu*, and have a very brilliant appearance. This may fometimes be placed in the focus of a parabolic reflector. In cafes where the light is required to be thrown to a diftance, other burners are conftructed upon the fame principle as the Argand lamp, forming a cylinder of flame, and admitting a current of air both to the infide and outfide.

Fig. 1. of *Plate* XVII. *Mifcellany*, is a fection of an apparatus for producing the gas adopted by Mr. Samuel Clegg of Manchefter, and communicated to the Society of Arts in 1808, when they voted Mr. C. a filver medal for the communication. A reprefents a caft iron retort, in which are put the coals, to be decompofed by the heat of a fire applied beneath it. The retort is fituated in a chamber reprefented by the dark fpace, in which the flame from the coals placed upon the grate B circulates all round the retort, and efcapes by the chimney D; E is the afh-pit beneath the grate; the double thicknefs of metal beneath the retort denotes a faddle or half cylinder of caft iron, which preferves that part of the retort which is moft expofed, and caufes it to be heated more uniformly; F is the mouth where the coals are introduced, it has a flaunch and a cover ground together, air tight, and faftened by a fcrew in the centre, or by one at each fide: *a* is an iron pipe conducting from the retort to a veffel

G, ſituated beneath the gazometer: in this veſſel the tar and other condenſible products are ſeparated from the gas, which aſcends the pipe *b*. The upper end of this is covered in the manner of a hood by a cylindric veſſel *d*, open at bottom, but partially immerſed beneath the ſurface of the water contained in the ciſtern of the gazometer, and perforated round, near the lower edge, with a number of ſmall holes. The gas diſplaces the water from the receiver *d*, and eſcapes through the ſmall holes riſing in bubbles through the water, ſo as to expoſe a large ſurface to its action, that it may be waſhed and purified from any ſmell. After riſing through the water, the gas enters the gazometer H H, which is ſuſpended to move up and down by the chains and pulley *e e*, and balance weights *f*, *f*. In the centre of the gazometer a tube *g* is fixed, having ſome ſmall holes at its upper end, by which it communicates with the interior of the gazometer. This tube includes another, *h*, fixed perpendicular from the bottom of the ciſtern, and communicating with others *k*, which convey the gas to the burners. The fixed pipe *h* forms a guide to keep the gazometer always perpendicular; and the pipe in the centre of the gazometer prevents any gas paſſing away except it has aſcended to the top of that veſſel, and is tranſparent and fit for uſe. The gazometer is made of iron plate rivetted together, and ſuſtained by a ſtrong hoop at top and another at bottom. Each hoop has radial bars which ſupport the tube *g* in the centre, and at the ſame time they ſtrengthen the whole. The gazometer muſt be painted within and without to preſerve it from ruſting. Mr. Clegg ſays, a veſſel of this kind, to contain 700 cubic feet of gas, will weigh about 20 cwt.

When the operation commences, the gazometer is ſunk down nearly to a level with the ſurface of the water in the ciſtern L L; but as the gas enters, it riſes up to receive it. It is to be noted, that the balance weights *f*, *f*, ſhould not be quite ſo heavy as the gazometer, in order that ſome preſſure may be exerted, to force the gas out of the burners with a proper jet. The gas which iſſues from the retort enters the receiver G, aſcends the pipe *b*, into the veſſel *d*, from which it diſplaces the water, and paſſes out at the ſmall holes as before deſcribed, riſing through the water into the gazometer, and raiſing it up: the gas then paſſes away to the burners. In this manner the proceſs proceeds, until the whole of the volatile products of the coals in the retort is evaporated. The uſe of the gazometer is, to equalize the emiſſion of the gas which comes from the retort more quickly at ſome time than others. When this happens, the veſſel riſes up to receive it, and when the ſtream from the retort diminiſhes, the weight of the gazometer expels its contents. When the proceſs is finiſhed, the retort is ſuffered to cool, and its lid is then removed to repleniſh it with coal. The caput mortuum, which is found in the retort, is the moſt excellent coak, and in value returns a conſiderable portion of the whole expence of fuel when the retort cools. The veſſel *d* contains a ſufficient quantity of gas to ſupply any abſorption which takes place without raiſing the water into the retort.

In Mr. Clegg's original apparatus the chains for the balance weight are attached to the top of the gazometer; and the ciſtern L, for containing the water of the gazometer, is repreſented as a well ſunk in the ground. This method is cheap and ſimple, though at the ſame time it is liable to have leaks, which are not eaſily diſcovered or acceſſible to be ſtopped; and it requires conſiderable length of pipes to draw off the matter from the receiver G; whereas in the conſtruction repreſented in the plate, they are drawn off by the cock at *x*. Of theſe products we ſhall ſpeak more in another place.

Figs. 2 and 3 repreſent one of the gas lamps on the principle of Argand; the ſpace between the two concentric tubes *a*, *b*, is ſupplied with gas by a pipe, *c*, in which is a cock, *d*, to regulate or occaſionally intercept the gas. The ſpace between the two tubes is covered at top with a circular ring, ſhewn in *fig.* 2, pierced with a number of ſmall holes, at which the gas iſſues, forming a cylinder of flame, to which a current of air is brought through the internal tube *d*. The air has alſo paſſage beneath the glaſs chimney, *f*, to ſupply the outſide of the flame, which is rendered the moſt ſteady and regular imaginable, by the draught cauſed by the chimney: *g* is a ſmall button affixed to a ſtem, which ſlides up and down in the interior tube with ſufficient friction to retain its poſition. The button conveys the current of air riſing through the tube in an expanded cone to the inſide of the flame, and aſſiſts the combuſtion in a great degree.

The next apparatus for gas lights which we ſhall deſcribe is by Dr. Stancliffe, as ſhewn in *fig.* 4. A is a veſſel of caſt-iron, forming the retort, and is ſet in brick-work in any proper furnace; E is a rim caſt in the ſame piece, incloſing the top of the former, ſo as to make a deep groove all round in the top of the veſſel. In this groove the head, F, of the veſſel is received; and to make the fitting air-tight, a quantity of fuſible alloy is placed in the groove. This melts by the heat of fire, and forms a fluid luting, which prevents the eſcape of the gas. G is a tube leading from the head to the refrigeratory E F; the joining of this tube with this veſſel is formed by a joint, on a ſimilar principle to the joining of the head with the retort: *a* is a tube paſſing through the lid of the veſſel, and another, *b*, is fixed concentric to and ſurrounding the former at a ſmall diſtance. The ſpace between theſe is filled with water, and the tube, G, which connects with the head, is immerſed in the water which forms the joint round the pipe, and by this means the tube, G G, and the head, F, of the retort, can be removed together to take out the coak and introduce freſh coals. The refrigeratory is made in two diviſions E and F, one above the other; the tube G goes down nearly to the bottom of the loweſt diviſion, and the gas bubbles up from the end of it through the water, with which the lower partition is partly filled: it then paſſes out at the pipe, *d*, to the burners. Theſe muſt not be of ſuch a number as to conſume the gas as faſt as the retort produced it; by this means it will be under a conſiderable preſſure in the veſſel, which is found conducive to the ſeparation of the tar, &c. When the gas comes over quickly from the retort, it preſſes upon the ſurface of the water, and cauſes it to aſcend through the pipe, *e*, in the partition into the upper chamber, where its weight conſtantly acts to cauſe a preſſure, and expel the gas at the pipe, *d*, whenever the ſupply of the retort diminiſhes; *f* is another pipe through the partition to allow the eſcape of the gas, if it forces out the water ſo low as the bottom of the pipe: the gas which then riſes into the upper diviſion gets away by the pipe *g* into the chimney of the funnel. Dr. Stancliffe has recently taken out a patent for the method of luting of the head and joint at G, as applied to the diſtillation of any other matter.

Fig. 5. is an apparatus by Mr. B. Cooke of Birmingham, recently communicated by him to the Society of Arts, and rewarded by them with a ſilver medal. The pipe A leads the gas from the pot or retort, and is fitted, in a manner ſimilar to Dr. Stancliffe's, to a veſſel B B, called the purifier. This is filled half full of water, and has five partitions, *a*, *a*, *a*, *a*, *a*, ſoldered to the lid, and extending beneath the ſurface of the water; at the lower edge a number of holes are pierced in the plates through which the gas iſſues, and riſes in bubbles through the water on the oppoſite ſide. In this manner it proceeds through all the plates, and is by that means waſhed and purified moſt perfectly, the cold water condenſing and depoſiting in the bottom of the veſſel the tar and ammoniacal liquor, which can be drawn off by the

cock *b*; M is the pipe which conveys the gas away from the end of the purifier, and leads it to the bottom of the tube, L L, of the gazometer, which is omitted in the drawing, as it is the fame as in Mr. Clegg's apparatus, and *furnished with balance weights in the fame manner*: *N* is the pipe to take the gas away to the burners. Mr. Cooke has placed his connecting pipes, M and N, inclined, and at the loweft point a fhort pipe *n*, which is immerfed in the water contained in a veffel *m*, fo as to prevent the efcape of any gas, but at the fame time to allow any tar, &c. to drain down the pipe and depofit itfelf in the water. By this means the tar, which will unavoidably reft in thefe pipes, is difpofed of without danger of clogging or ftopping the paffage, as might happen in courfe of years, though the quantity was ever fo minute. Mr. Cooke recommends for dwelling-houfes, where the gas is required to be particularly free from fmell, that it fhould be paffed through a fecond purifier containing lime water, which will render it perfectly pure.

In any of thefe apparatufes, it is effential that the water ufed for wafhing and purifying the gas fhould be changed for frefh as foon as it becomes dirty; and unlefs this is done the gas will not be perfectly purified by wafhing, but retain an unpleafant fmell after it. The tar which depofits itfelf at the bottom of the veffel, in the confiftence of treacle or thick oil, is firft drawn off by the cock: for that purpofe this fubftance is found very ufeful, and in many points forms a fubftitute for the vegetable tar. By boiling it, the volatile parts are evaporated, and it becomes pitch. If the evaporation is performed in a retort, the matter which comes over is a fpirit, which, according to Mr. Cooke, may be ufed inftead of that kind of turpentine, known by the term tar fpirit, in painting and japanning: and he gives particular directions for the manner of performing this diftillation in the 28th vol. of the Tranfactions of the Society of Arts. The refiduum left in the retort is pitch; or, if further boiled, makes afphaltum, or a fubftance which is equally applicable, for the various arts in which it is employed.

It is proper that we fhould here notice Mr. Winfor's procefs for procuring gas, coak, and many other products, from pit-coal: but as this procefs has not been wholly made public, our notice muft be fhort. A company has been eftablifhed for the purpofe of carrying into execution his invention, and has applied to parliament for powers to act as a corporate body. Thofe who form this body, propofe to erect apparatufes, in convenient fituations, and convey the gas by pipes along the ftreets of a town, for the purpofe of lighting them, as well as the houfes. Experiments were made of this plan by lighting one fide of Pall Mall, in London, which appeared to anfwer well; and the company's houfe has been conftantly lighted and heated by gas fince the firft eftablifhment.

Mr. Winfor, at the opening of the bufinefs, gave lectures and experiments on the gas, though the manner of procuring and purifying it he kept a fecret: he exhibited the mode of conducting it through the houfe, and a number of elegant devices for chandeliers, &c. by which it was confumed. Among thefe he propofed long flexible tubes fufpended from the ceiling of the room, and at the end communicating with a burner, which was defigned with much tafte, being a cupid holding a torch in one hand, and grafping the tube, in the fame manner, as a rope in the other. This figure was to be fufpended by hooks in any convenient part of the room where light was required, and might be carried into any clofet or other place within the limits of the length of the tube. He fhewed alfo by experiments, that the flame of the gas was not liable to be extinguifhed by wind or rain, that it produced no fmoke, and was not fo dangerous as the light of lamps or candles, as it could not produce fparks.

A pamphlet has been recently publifhed by Mr. Van Voorft, ftating the evidence taken before the committee of the houfe of commons appointed upon the bill, for the incorporation of the Gas Light Company. This gentleman ftates the products of a London chaldron of coals, treated in Mr. Winfor's procefs, to be, 1ft, light by the combuftion of the gas equal to 2,100 parifh lamps burning 11 hours: 2d, $1\frac{1}{2}$ chaldron of coak by admeafurement: 3d, 60lbs. of pitch: 4th, three gallons of effential oil: and, 5th, 18 gallons of ammoniacal liquor; and he enters into a calculation of the pecuniary profits; but this we forbear to detail, as being entirely dependent upon the local fituation and value of the coals and their products. This ftatement is collected chiefly from the evidence of Mr. Accum. The bill was rejected by parliament; but we underftand, by the above pamphlet, that the company intend to profecute their undertaking without a charter of incorporation.

Mr. Murdoch made a communication in 1808 to the Royal Society on the fubject of gas light, and was complimented with count Rumford's medal for the fame. He gives the refults of the procefs as conducted in the cotton mills of Meffrs. Phillips and Lee, at Manchefter, who have a very large apparatus conftructed by Mr. M. at the Soho works. The gas lights are equal to 2500 mould candles of fix in the pound, each candle confuming 175 grains of tallow per hour. The number of burners are 271 Argands, and 633 cockfpurs, fo called from having three jets diverging from each other. Thefe require an hourly fupply of 1250 cubic feet of gas to produce, which requires feven cwt. of cannel coal in the retort, and about one third of that quantity of good common coal to heat the retort. The cannel coal in the retort produces nearly $4\frac{1}{2}$ cwt. of good coak, and $4\frac{1}{2}$ ale gallons of tar. The ammoniacal liquor was not regarded, as it has not yet been applied to any manufacture, fo as to be demanded in large quantities; though a paper by Mr. Wm. Cox will be found in Mr. Van Voorft's pamphlet, fhewing the advantages of the ammonia as applied for manure, and fome other experiments on its ufe in dyeing. See Flame.

Gauge

GAUGE, in *Engineery*, ſometimes ſignifies the ſame with weir: a gauged bar is an upper gate, or over-fall to a weir. See Smeaton's Reports, vol. i. p. 62.

GAUGE-*line*, a line on the common gauging-rod, whoſe deſcription and uſe ſee under the article GAUGING.

GAUGE-*point* of a ſolid meaſure is the diameter of a circle, whoſe area is equal to the ſolid content of the ſame meaſure.

Thus the ſolidity of a wine gallon being 231 cubic inches: if you conceive a circle to contain ſo many inches, the diameter of it will be 17.15: and that will be the gauge-point of wine meaſure.

And an ale-gallon containing 282 cubic inches; by the ſame rule, the gauge-point for ale-meaſure will be found to be 19.15: and after the ſame manner may the gauge-point of any other meaſure be determined.

Hence we deduce, that when the diameter of a cylinder in inches is equal to the gauge-point in any meaſure (given likewiſe in inches) every inch in length thereof will contain an integer of the ſame meaſure. In a cylinder, whoſe diameter is 17.15 inches, every inch in height contains one entire gallon in wine-meaſure; and in another, whoſe diameter is 19.15, every inch in length contains only one ale-gallon.

GAUGE-*weir*, in *Engineery*, is a weir or over-fall, out of ſome reſervoir, or pound of a canal, calculated to diſcharge a given quantity of water daily, for the ſupply of mills, or ſome other canal. See CANAL.

GAUGER, an officer appointed by the king to gauge, *i. e.* to examine or meaſure, all caſks, tuns, pipes, barrels, hogſheads of beer, wine, oil, &c. and to give them a mark of allowance (which is a circle burnt with an iron) before they be ſold in any place within the extent of this office.

Of this officer and his office we have many ſtatutes; thus, by 27 Edw. III. c. 8. all wines, &c. imported, are to be gauged by the king's gaugers or their deputies; by 31 Edw. III. c. 5. ſelling wine before gauged, incurs forfeiture, or the value: and by 23 H. VI. c. 15. the gauge penny is to be paid gaugers on gauging wines. The 31 Eliz. ordains that beer, &c. imported ſhall be gauged by the maſter and wardens of the Coopers' company: ſee 12 Car. II. c. 4. The wardens of the Coopers ſhall attend to gauge veſſels upon requeſt. 23 Hen. VIII. c. 4. Gaugers may take ſamples not exceeding half a pint, 32 Geo. II. c. 29. See EXCISE.

GAUGING, the art or act of meaſuring the capacities or contents of all kinds of veſſels, and determining the quantity of fluids or other matters contained therein.

Gauging is the art of reducing the unknown capacity of veſſels of divers forms, cubical, parallelepipedal, cylindrical, ſpheroidal, conical, &c. to ſome known cubic meaſure; and of computing, for inſtance, how many gallons, quarts, pints, or the like, of any liquor, *e. gr.* ale, beer, wine, brandy, &c. are contained therein.

Gauging is a branch of ſtereometry.

The principal veſſels that come under its operation are pipes, barrels, rundlets, and other caſks; alſo backs, coolers, vats, &c.

The ſolid content of cubical, parallelepipedal, and priſmatical veſſels, is eaſily found in cubic inches, or the like, by multiplying the area of the baſe by the perpendicular altitude.

And for cylindrical veſſels, the ſame is found by multiplying the area of the circular baſe by the perpendicular altitude, as before.

Caſks of the uſual form of hogſheads, kilderkins, &c. may be conſidered as ſegments of a ſpheroid cut off by two planes perpendicular to the axis: which brings them to Oughtred's theorem for meaſuring ale and wine caſks, which is thus: add twice the area of the circle at the bung to the area of the circle of the head; multiply the ſum by one-third of the length of the caſk, the product is the content of the veſſel, in cubic inches. But for accuracy, Dr. Wallis, Mr. Caſwell, &c. think, that moſt of our caſks had better be conſidered as fruſtums of parabolic ſpindles, which are leſs than the fruſtums of ſpheroids of the ſame baſe and height, and give the capacity of veſſels nearer the truth than either Oughtred's method, which ſuppoſes them ſpheroids; or than that of multiplying the circles of the bung and head into half the length of the caſk, which ſuppoſes them parabolic conoids: or than that of Clavius, &c. who takes them for two truncated cones: which is fartheſt off of all.

The common rule for all wine or ale caſks is to take the diameters at the bung, and at the head, by which you may find the area of the circle there; then taking two-thirds of the area of the circle at the bung, and one-third of the area of the circle at the head, and adding them together into one ſum, this ſum, multiplied by the internal length of the caſk, gives the content in ſolid inches; which are converted into gallons, by dividing by 282 for ale, and by 231 for wine gallons.

The readieſt method for common uſe is to reduce the caſk

to a cylinder of equal contents; and this is done by considering what is called the variety of the cask. Suppose a cylinder inscribed in a cask, and another circumscribed about it, there will be a cylindrical space included between the superficies of the two cylinders, whose diameter or thickness is equal to the difference between the bung and head diameters of the cask; the curvature of the staves of the cask takes in a certain proportion of the cylindrical space, which is greater or less, as the curvatures bend, or bulging of the staves is greater or less; and this determines what is called the variety; and it will be the first variety, if the cask bulges very much; second variety, if less, and so on: it is, therefore, evident, that the diameter of the inscribed circle may be increased so as to take in a portion of the interjacent cylindrical space equal to that taken in by the curvature of the staves of the cask; and then the cask and increased cylinder will be equal in content. The diameter of the inscribed cylinder is the head diameter of the cask; the thickness of the cylindrical space is equal to the difference between the bung and head diameters. The only difficulty, therefore, lies in determining what portion of this difference must be added to the head diameter of the cask, in order to obtain the diameter of the mean cylinder, or the cylinder of equal content. Now experience shews, that if 7-10ths of the difference between the head and bung diameters of any cask be added to the head diameter, the cylinder whose diameter is equal to this sum, and whose length is equal to that of the cask, will contain as much or more than that cask, though the staves have the greatest degree of curvature that is ever given to them. And as the difference between the bung and head-diameters of casks is seldom very great, the contents of a cask whose staves are quite straight from bung to head, or of a cask made up of two equal frustums of two equal cones, will generally be nearly equal to the contents of a cylinder, whose diameter is equal to the sum of the head diameter of the cask, and a little more than half the difference between the bung and head diameters, and whose length is equal to the length of the cask. Therefore, all the varieties of which casks are capable, lie between 5-10ths and 7-10ths of the difference between the bung and head diameters; and the gauger has only to take such a part of this difference (always between 5-10ths and 7-10ths) as his judgment and experience inform him to be most suitable to the curvature of the cask; and this, added to the head diameter, gives the diameter of the mean cylinder.

It may not be amiss to note here, that the difference between the bung and head diameters may be very great, and yet the cask have no bulging at all, for the bulging is the bend or curvature of the half-stave, between the bung and the head.

Mathematicians give us abstruse theorems, for computing the contents of casks, upon the supposed resemblance between the curvature of the cask and that of an ellipsis, parabola, or hyperbola; but they may be as much mistaken in judging of the curvature, as an experienced gauger between 5-10ths and 7-10ths: for after all, the contents of casks cannot be determined to a mathematical exactness; because the forms of casks do not exactly answer any mathematical figures. The business of gauging is at best but guess-work; but it is such a way of guessing, as comes near enough the truth for the common purposes of life.

Hence we may add such decimal multipliers, for the difference between bung and head diameters as have been found by experience to be the truest, and best suited to the several varieties or curvatures of casks.

First variety, or staves very much bulging,	.7 or .695
Second variety, or staves not so much curved,	.65 or .63
Third variety, or staves still less curved,	.6 or .56
Fourth variety, or staves almost straight,	.55 or .51

The following rule will serve for gauging casks by the pen: take the difference of the bung and head diameters of any cask, and multiply that difference by the number which stands against the name of the cask given in the table, add the product to the head diameter; and the sum will be the diameter of a cylinder, which, being of the same length with the given cask, will contain as much; square the diameter thus found, and multiply that square by the length, and divide the product by 359 for beer gallons, and 294 for wine.

The multipliers for a cask, which is taken for varieties:

The middle frustum	1. Of a spheroid	.7	greatest bulge.
	2. Of a parab. spindle	.63	next less.
	3. Two conoids	.56	next less to that.
	4. Two cones	.51	next less to that.

Example.—Let a cask be taken as the middle frustum of a spheroid, the bung diameter of which is 32 inches, the head 26, and length 50 inches; what is the content in beer and wine gallons? $\overline{32 - 26} \times .7 = 4.2$. To which add 26, and we shall have 30,2 for the mean diameter; and $\overline{30.2}|^2 = 912.04$, which multiplied by the length 50 will give 45602; and $\frac{45602}{359} = 127$ beer gallons; and $\frac{45602}{294} = 155.1$ wine gallons. The contents of other casks may be found in the same manner by using the proper multipliers. See Everard's SLIDING *rule*.

For the ready computation of the contents of vessels, or of any solids in the measures in use in Great Britain, we shall here insert the following rules taken from a Treatise of Practical Geometry, published at Edinburgh in 1745, 8vo. Vide pag. 137. seq.

1°. To find the content of a cylindric vessel in English wine gallons, the diameter of the base and altitude of the vessel being given in inches and decimals of an inch: square the number of inches in the diameter of the vessel; multiply this square by the number of inches in the height, then multiply this product by the decimal fraction 0.0034, and you will have the contents of the vessel in gallons, and decimals of a gallon. For example, let the diameter be $= D = 51.2$ inches, the height $= H = 62.3$ inches, then will the content be $D\,D\,H \times 0.0034 = 51.2 \times 51.2 \times 62.3 \times 0.0034 = 555.27342$ wine gallons.

2°. Supposing the English ale gallon to contain 282 cubical inches, the content of a cylindric vessel is computed in such gallons, by multiplying the square of the diameter of the vessel by its height as before, and their product by the decimal fraction 0.0027851, that is, the solid content in gallons will be $D\,D\,H \times 0.0027851$.

3°. If the Scotch pint contains 103.4 cubical inches, the content of such a vessel in Scotch pints, will be $D\,D\,H \times 0.0076$.

4°. Supposing the Winchester bushel to contain 2178 cubic inches, the content of a cylindric vessel is computed in those bushels, by multiplying the square of the diameter of the vessel by the height, and the product by the decimal fraction 0.0003606. But the legal Winchester bushel containing only 2150.42 solid inches, the content of a cylindric vessel is computed in such bushels, by multiplying the square of the diameter by the height, and their product by the decimal 0.0003652. Or the content will be $D\,D\,H \times 0.0003652$ See BUSHEL.

5°. Supposing the Scotch wheat firlot to contain $21\frac{1}{4}$ Scotch pints, or about 2197 cubical inches, the contents of a cylindric vessel in such firlots will be $D\,D\,H \times 0.000358$.

And if the beer firlot contain 31 Scotch pints, the contents of fuch a veffel in beer firlots will be D D H × 0.000245. See FIRLOT.

6°. It is to be obferved, that when the fection of the veffel is not a circle, but an ellipfis, the product of the greateft diameter by the leaft is to be fubftituted in thefe rules, for the fquare of the diameter.

7°. To compute the content of a veffel, which may be confidered as the fruftum of a cone in any of thofe meafures. Let A reprefent the number of inches in the diameter of the greater bafe, B the number of inches in the diameter of the leffer bafe. Compute the fquare of A, the product of A by B, and the fquare of B. Take the third part of the fum of all thefe, and fubftitute it in the preceding rules for the fquare of the diameter, and proceed in all refpects as before. Thus for example, the content in wine gallons will be $A A + A B + B B \times \frac{1}{3} H \times 0.0034$. Or thus: To the fquare of half the fum of A and B add one-third of the fquare of half their difference; and fubftitute this fum in the preceding rules for the fquare of the diameter of the bafe of the veffel. For the fquare of $\frac{1}{2} A + \frac{1}{2} B$ added to $\frac{1}{3}$ of the fquare of $\frac{1}{2} A - \frac{1}{2} B$ gives $\frac{1}{4} A A + \frac{1}{2} A B + \frac{1}{4} B B + \frac{1}{12} A A - \frac{1}{6} A B + \frac{1}{12} B B = \frac{1}{3} A A + \frac{1}{3} A B + \frac{1}{3} B B$.

8°. When the veffel is a fruftum of a parabolic conoid, meafure the diameter of the fection at the middle of the height of the fruftum: and the content will be the fame as of a cylinder of this diameter, of the fame height with the veffel.

9°. When a veffel is a fruftum of a fphere, if you meafure the diameter of the fection at the middle of the height of the fruftum, then compute the content of a cylinder of this diameter, and of the fame height with the veffel, and from this fubtract $\frac{1}{3}$d of the content of a cylinder of the fame height, on a bafe, the diameter of which is equal to that height; the remainder will give the content of the veffel. That is, if D reprefent the diameter of the middle fection, and H the height of the fruftum, you are to fubftitute $D D - \frac{1}{3} H H$ for the fquare of the diameter of the cylindric veffel in the firft fix rules.

10°. When the veffel is a fruftum of a fpheroid, if the bafes are equal, the content is readily found by the rule given from Oughtred. In other cafes, let the axis of the folid be to the conjugate axis, as n to 1; let D be the diameter of the middle fection of the fruftum, H the height or length of the fruftum, and fubftitute in the firft fix rules $D D - \frac{H H}{3 n n}$ for the fquare of the diameter of the veffel.

11°. When the veffel is a hyperbolic conoid, let the axis of the folid be to the conjugate axis as n to 1, D the diameter of the fection at the middle of the fruftum H, the height or length, compute $D D + \frac{H H}{3 n n}$, and fubftitute this fum for the fquare of the diameter of the cylindric veffel in the firft fix rules.

12°. In general, it is ufual to meafure any round veffel, diftinguifhing it into feveral fruftums, and taking the diameter of the fection at the middle of each fruftum; thence to compute the content of each, as if it was a cylinder of the mean diameter; and to give their fum as the content of the veffel. From the total content computed in this manner they fubtract fucceffively the numbers which exprefs the circular areas that correfpond to thofe mean diameters, each as often as there are inches in the altitude of the fruftum to which it belongs, beginning with the uppermoft; and in this manner calculate a table for the veffel, by which it readily appears how much liquor is at any time contained in it, by taking either the dry, or the wet inches; having regard to the inclination, or drip of the veffel, if it has any.

This method of computing the content of a fruftum from the diameter of the fection at the middle of its height, is exact in that cafe only when it is a portion of a parabolic conoid; but in fuch veffels as are in common ufe the error is not confiderable. When the veffel is a portion of a cone or hyperbolic conoid, the content by this method is found lefs than the truth; but when it is a portion of a fphere or a fpheroid, the content computed in this manner exceeds the truth. The difference or error is always the fame in different parts of the fame, or fimilar veffels, when the altitude of the fruftum is given. And when the altitudes are different, the error is in the triplicate ratio of the altitude. If exactnefs be required, the error in meafuring the fruftum of a conical veffel, in this manner, is $\frac{1}{4}$th of the content of a cone, fimilar to the veffel, of an altitude equal to the height of the fruftum. In a fphere it is $\frac{1}{3}$d of a cylinder, of a diameter and height equal to the fruftum. In the fpheroid and hyperbolic conoid, it is the fame as in a cone, generated by the right-angled triangle contained by the two femiaxes of the figure revolving about that fide which is the femiaxis of the fruftum. Thefe are demonftrated in a treatife of fluxions by Mr. Maclaurin, where thofe theorems are extended to fruftums that are bounded by planes oblique to the axis in all the folids, that are generated by any conic fection revolving about either axis. Vide p. 25. and 715.

In the ufual method of computing a table for a veffel, by fubducting from the whole content the number that expreffes the uppermoft area, as often as there are inches in the uppermoft fruftum, and afterwards the numbers for the other areas fucceffively, it is obvious that the contents affigned by the table, when a few of the uppermoft inches are dry, are ftated a little too high, if the veffel ftands on its leffer bafe, but too low when it ftands on its greater bafe; becaufe, when one inch is dry, for example, it is not the area at the middle of the uppermoft fruftum, but rather the area at the middle of the uppermoft inch, that ought to be fubducted from the total content, in order to find the content in this cafe.

But gauging, as now practifed, is chiefly done by means of inftruments called *gauging-rods*, or *rules*, which do the bufinefs at once, and anfwer the queftion without fo much calculation; which is no inconfiderable addition, both to the eafe and difpatch of the work. This inftrumental way of gauging, therefore, we fhall here chiefly infift upon.

Dr. Hutton in his "Menfuration" has given rules for computing the contents of the various fruftums of folids, which bear refemblance to the feveral varieties or forms of different cafks. Rules adapted to thefe forms will be found under the denominations of the feveral folids to which they belong in this Cyclopædia; and they occur in moft books, profeffedly written on the fubject of Gauging. We fhall here fubjoin one general rule, extracted from the abovecited treatife, (p. 592) which may be eafily applied to the cafes that occur.

General Rule.

Add into one fum 39 times the fquare of the bung diameter,
25 times the fquare of the head diameter,
and
26 times the product of thofe diameters.
Multiply the fum by the length of the cafk, and the product by the number .00034; then this laft product divided by 9

Gazometer

GAZOMETER, Gasometer, or *Gas-holder*, are names given to certain inftruments or veffels formed as refervoirs for large quantities of gas, to which are added fuitable conveniences for receiving and applying the fame, and for meafuring the volume. Lavoifier and Meufnier were the firft to defign and execute fuch an inftrument, of which a plate, accompanied with a defcription, was given in the Elements of Chemiftry, publifhed by the former celebrated philofopher in 1789. This inftrument was too complicated and expenfive to be of general ufe. Since that time various have been the alterations and improvements made by fucceeding chemifts according to the objects they had in view.

Lavoifier's gazometer confifted of a cylindrical copper veffel, open at bottom, and inferted into another larger veffel of the fame kind, open at top. The internal veffel is 18 inches in diameter, and 20 inches deep. Around the bottom of this, on its outfide, is fixed a border divided into compartments, intended to receive leaden weights, 1, 2, 3, 4, &c. in order to increafe the weight of the veffel when confiderable preffure is requifite. The top of this veffel is furnifhed with a tube and ftop-cock, forming a communication between the external and internal air, alfo with a thermometer cemented into it to fhew the temperature of the air within. The veffel is fupported by a chain from one of the circular ends of a balance beam; and to the other end a fcale and weight are fufpended as a counterpoife. The external veffel is partly filled with water, and has tubes along the bottom and rifing up to communicate with the air in the interior veffel, for the purpofe of admitting or difcharging it. Some auxiliary glafs tubes and a fcale of inches are attached to the veffel, to fhew the height of the water in the inner and outer veffel, and the difference of the heights, in order to correct for the preffure. This partial defcription will give an idea of the outline of the ftructure, which is much too complicated to be exhibited as a model for the prefent time.

In the 12th vol. of the Annales de Chimie, 1792, is given the defcription of a gazometer by Van Marum: the immediate object of it was to exhibit the compofition of water by the flow combuftion of hydrogen in a large glafs receiver. Two of thefe gazometers were employed; the one to introduce a ftream of hydrogen gas, and the other oxygen. The hydrogen was lighted at the commencement of the experiment by electricity. The apparatus difplays ingenuity; but it is complicated and expenfive. In the 14th vol. of the fame work he gives a fimplification of the gazometer as applied to the fame purpofe; but it is ftill too complex and too partial in application for general ufe.

In 1794, Mr. Watt of Birmingham publifhed a pamphlet containing a defcription of an apparatus for elaftic fluids. In this he defcribes two veffels, the one under the name of *hydraulic bellows*, which is, in fact, the modern gazometer, and the other under the name of *air-holder*. Thefe were illuftrated with plates. The hydraulic bellows or gazometer confifts of two veffels H and J, *Plate* XIV. (*Chemiftry*) *fig.* 1. The outer veffel, H, confifts of two cylinders placed one within the other, and about half an inch afunder. Thefe cylinders are joined together at bottom by a circular rim, well foldered to them both; and the inner cylinder is fhut at top by a cover alfo foldered on. This inner cylinder is about two inches fhorter than the outer cylinder, and the latter is furmounted by a cup, W W, about 1½ inch deep, and one inch all around more in diameter than the cylinder to which it is attached. The pipe, P Q, paffes diametrically acrofs the veffel H; the end, Q, is open, and made fo as to be ftopt with a cork or cock. From this pipe, P Q, proceeds a pipe V, which paffes upwards through the cover of the inner cylinder to which it is foldered, and is open at its upper end. The fecond veffel, J, of the bellows, is a hollow cylinder of one foot diameter, and eighteen inches long, fhut at top, and open at bottom; it is made fo as to move up and down eafily in the circular interftice between the inner and outer cylinders of the veffel H; and when that interftice is filled with water, as high as the cover of the inner cylinder, if the veffel J is moved up and down, it will act the part of a bellows, drawing in and blowing out air, by the pipes V and P Q. The bellows are made of tinned iron plates japanned, or of tinned copper-plates not japanned.

The air-holder is thus defcribed: Let a cylindrical veffel (*fig.* 2.) be made of ftrong tin plate; this veffel is to be clofe at both ends, which are made concave outwards; clofe to both the bottom and cover, fhort pipes, U and V, proceed from the fide of the veffel; their diameters fhould be the fame as the pipe, P Q, of the bellows. Another pipe, T, paffes through the middle of the cover or upper end of the veffel, to which it is well foldered; and reaches within half an inch of the bottom. To guard this veffel from ruft it fhould be japanned both infide and out; and for the greater convenience of japanning it within, it may be made to come afunder at the middle of its height, and when varnifhed may be cemented together by a mixture of wax and rofin ufed hot. When this veffel is completed, the upper pipe, U, is to have a fhort pipe, W, inferted into it, which fhould alfo fit the pipe, Q, of the bellows. The lower pipe, V, is then to be corked, and the veffel filled with water by the central pipe T. This veffel is to be placed in an empty tub, the pipe, W, inferted into the pipe, Q, of the bellows, and cemented to it. When the bellows are filled with artificial air, the cork of the lower pipe, V, is to be taken out, and the counterpoife of the bellows is to be lifted up; the water in the air-holder will then run out into the tub, and the air defcend from the bellows into the former veffel, which, when full, muft have its pipes clofe corked. To transfer the air from this veffel into a bag or bladder, fix the faucet or mouth-piece of the bag or bladder into the upper pipe U, and if you want a quart or gallon, or other meafure of air, pour fo much water into the air-holder through the central pipe, and exactly that quantity of air will iffue out; then re-cork your veffel until you want more air from it.

In the 5th vol. of the Philofophical Magazine 1799, Mr. Pepys defcribes a new mercurial gazometer. The principle of it is nearly the fame as the hydraulic bellows of Mr. Watt. A (*fig.* 3.) is a reprefentation of the bell of the ga-

zometer, made of glafs, furnifhed with a cock at top, and able to contain 34 ounces Troy of diftilled water. The divifions of capacity, determined by actual meafurement, are marked on the glafs with a diamond. B B, are the fections of two cylinders of lignum vitæ (or caft iron), the outward one fcrewed upon the folid internal one, which is made to project at its lower extremity, and furnifhed with a male fcrew, to work into a female fcrew, with which the lower end of the external cylinder is furnifhed. The fpace between thefe is fo adjufted as to be almoft filled up by the fubftance of the glafs bell, A, when dropped into it, fo that the quantity of mercury neceffary to fill up that fpace is proportionally fmall. The internal cylinder has a conducting tube up through its axis, the lower end of which is furnifhed with a female fcrew anfwering to the male fcrew of the cock of the fmall receiver C. The receiver, C, is of glafs, and open at the bottom. When this receiver is ufed, it is fcrewed into its place, and refts upon a fmall cup or ciftern of mercury, D, in which the beak of a retort, furnifhed with a bent glafs tube, may be introduced into the receiver. E E E E fection of a wooden ftand upon which the cylinders of lignum vitæ or caft iron are fupported, having an opening through the top to permit the cock of the receiver, C, to be joined to the conducting tube of the internal cylinder B. The ciftern, D, is adjufted to its height by means of a rifing cylinder in the pedeftal F. G is a transfer glafs for mixing alkaline gafes in vacuo, or other purpofes, and when ufed, is joined to the top of the bell A. H, a glafs globe and ftopcock, capable of holding 14 ounces Troy of water, for weighing gafes; it receives its gas by being inverted and fcrewed into the bell A. I, a bladder furnifhed with a ftopcock, to affift in holding, transferring, or mixing different gafes. K, an elaftic gum bottle capable of containing 30 ounces of water, for holding the acid gafes; when ufed it is fcrewed into the top of the transfer G; the bottom cock of the latter being at the fame time joined to the bell A, previoufly charged with the alkaline gas; the cocks being turned, the gafes rufh together in vacuo. L, a fmall portable air-pump for exhaufting the globe H. M, a double male fcrew, which fits any part of the apparatus, and on which a valve may be faftened. N, a double female fcrew. O, a fmall inftrument, of fervice in collecting fpilled mercury, or transferring fmall quantities of it.

Mr. Davy's Refearches, &c. publifhed in 1800, contain an account of a mercurial gazometer by Mr. Clayfield. The peculiarity of this confifts, in having the counterpoife to the cylinder fufpended by a ftring which runs in a fpiral groove fo as to balance the cylinder, whatever its depreffion in the mercury may be.

The 53d vol. of the Journal de Phyfique, 1801, contains a defcription of a new gazometer by Victor Michelotti, M.D. of Turin. This inftrument, however, can fcarcely be recommended for its fuperiority.

In the 13th vol. of the Philofophical Magazine, 1802, Mr. Pepys has defcribed a new gas-holder. The apparatus is in fome refpects fimilar to that recommended by Mr. Watt. A fmall circular ciftern is added at top, which is connected with the gas-holder by means of two pipes furnifhed with cocks. It has alfo a brafs cock on the fide, and a glafs gage or regifter tube, fhewing the quantity of included gas by the level of the water. The following is a defcription of the different parts, *fig* 4. The gas-holder, G, may contain from two to ten gallons. R, the regifter tube, the ends of which are cemented into two tin fockets by corks at the top and bottom of the gas-holder, into which it opens at both ends; of courfe the level of the water in the apparatus will always be feen in the tube, and confequently that of the gas. C, the circular ciftern with its two cocks and pipes, marked 1 and 2. C *k* a brafs cock on the fide, with a fcrew, to which bladders or a blow-pipe may be attached. O, an opening into the gas-holder, in which a pipe is foldered at fuch an angle, that when all the uppermoft cocks are fhut, no water can poffibly efcape. But when a conducting pipe from a retort or other apparatus generating gas, is introduced into this opening, then, as the gas paffes up into the gas-holder, an equal quantity of water will be difcharged at O into any veffel fit to receive it. S *p*, a fpout on the fide of the ciftern to enable the operator to add water, even when the receiver fills its whole area. H, H, handles to lift the gas-holder. R *r*, a glafs deflagrating receiver, ftanding in the ciftern. A, its adopting cork and cock. S, a watch fpring in a flit wire prepared for combuftion. The wire paffes through a cork. D, a deflagrating difk of iron for fulphur, phofphorus, charcoal, fugar, camphor, &c. B, a blow-pipe with a gum elaftic tube, E, capable of joining the cock C *k*.

To make ufe of this apparatus; firft fill the gas-holder with water, by clofing the opening, O, with a cork, and alfo the cock, C *k*, and keeping the circular ciftern full of water, while the cocks 1 and 2 are both open. The air is driven out of the gas-holder through the cock 1, by the water defcending into it by the cock 2. When full, the water in the regifter will be on a level with the top of the gas-holder. Then fhut the cocks 1 and 2. You may now remove the cork from the opening, O, which is then prepared to receive the conducting pipe from any apparatus from which the gas is generating. As the gas is delivered the water efcapes, and fhould be caught in any convenient veffel. The regifter will then fhew the quantity received; when full, clofe the opening, O, with a cork wrapped in leather, which prevents the communication with the atmofphere. It may now be eafily removed or conveyed where it is wanted. When it is required to fill a glafs receiver, as R *r*, with the gas, having previoufly filled the circular ciftern with water, place it in the ciftern, put in the adopting cork, A, and with the mouth applied to the cock, exhauft the receiver in which the water will rife till full. Then clofe the cock, A, and open the two cocks, 1 and 2, and the gas will afcend into the receiver, while the water will take its place in the gas-holder.

In the fame volume of the Magazine Dr. Warwick fuggefts a more fimple alteration of Mr. Watt's air-holder than the above. It confifts in having a rim at the top of Watt's air-holder, fo as to admit of a column of water of an inch in depth above the ftop cock, foldered to the fhorter tube in the top of the air-holder.

In the 23d vol. of Nicholfon's Philofophical Journal, 1809, Mr. Clegg has given a defcription of a gazometer or gas-holder for receiving the gas from coals, for the purpofe of lighting manufactories, &c. This is on a large fcale, fo as to hold feveral hundred cubical feet. The veffel containing the air is made of wrought iron plates, and may be cylindrical, or, which is better, fquare or oblong, with an internal frame of wood to preferve the figure. This veffel is balanced by a weight in the manner of other gazometers, and is let down into a large well or refervoir of water, like the upper cylinder of Mr. Watt's hydraulic bellows. When in operation, a fmall head of water preffes on the gas, and forces it through the tubes to the lamps, where it is burned. As this apparatus is daily receiving improvement, we fhall defer giving a full defcription of it till the article GAS-*Light*. See alfo LIGHT.

Rules for reducing meafures of gafes to weights.—In order to reduce any given meafure of a gas to weight, the exact

weight of a given volume at a certain pressure and temperature must be previously known. This may be seen in a table under the article GAS. The mean pressure of the atmosphere may be taken at 30 inches of mercury, and the mean temperature at 55° of Fahrenheit. The reduction, on account of pressure, arises from the principle that "the volume of any gas is inversely as the pressure." The reduction, on account of temperature, must be $\frac{1}{435}$th for every degree of Fahrenheit, between the limits of 32° and 80°. At least this is a sufficient approximation: that is, the volume must be *increased* if the temperature is below 55°, and *diminished* if above 55°, by the fractional part above specified.

Example 1.—Required the weight of 1000 cubic inches of common air in a mercurial gazometer; the mercury within being 2½ inches above the level of that without, the barometer at the same time being 29.5 inches, and the thermometer 62°.

Solution.—Here the real pressure of the gas is 29.5 — 2.5 inches = 27. Hence, 30 : 1000 :: 27 : 900 = the volume of gas reduced to 30 inches of pressure. Again, 62° — 55° = 7°, and $\frac{7}{435}$ of 900 = 14.5, which being taken from 900, leaves 885.5 cubic inches of gas at the common pressure and temperature. But 100 cubic inches weigh 31 grains; whence 885.5 × 31 = 274½ grains, as required.

Example 2—Required the weight of 1000 cubic inches of common air in a water gazometer; the water within being 3 inches below that without, the barometer at the same time being 29.8, and the thermometer 38°.

Solution.—Here the real pressure of the gas is 29.8 + the pressure of 3 inches of water; but 3 inches of water = $\frac{3}{13.6}$ inches of mercury = .22 inch. Whence the pressure = 30.02. And 30 : 1000 :: 30.02 : 1000.7, the volume of gas reduced to 30 inches of pressure. Again, 55° — 38° = 17°, and $\frac{17}{435}$ of 1000.7 = 39.1, which being added to 1000.7, gives 1039.8 cubic inches of gas at the common pressure and temperature = 322⅓ grains.

Gilbert

Gilbert, John, the son of Mr. Thomas Gilbert, a gentleman possessing an estate of about 300*l.* a year, was born in the year 1724. His eldest brother had a liberal education, with a view to the bar, and became afterwards a member of parliament for Newcastle and Litchfield; but the subject of this article had only such instruction as the obscure village of Farley, in the neighbourhood of his father's house, could afford. At the age of twelve or thirteen years, he was bound apprentice to Mr. Bolton, father of the well-known and justly celebrated Matthew Bolton, of Soho, near Birmingham; between whom and Mr. Gilbert an intimacy subsisted, as long as the latter lived. At the age of 19 he lost his father; and as he died possessed of extensive lime-works, they required attention. Accordingly Mr. Gilbert, in order to undertake the superintendence of them, quitted his connection with Mr. Bolton, who very reluctantly parted with him, and devoted himself to the management of his own family concerns. Notwithstanding the disadvantages under which Mr. G. had laboured in early life, he possessed talents, which, matured by age and experience, could not fail of recommending him to notice. But the most remarkable circumstance in the history of this ingenious person, and that indeed which has induced us to give a brief account of him, was his introduction to the duke of Bridgewater, at the time when he was projecting improvements of his collieries, in the neighbourhood of Manchester. Mr. Gilbert's brother was then steward to the duke; and desired him to inspect and examine his Grace's collieries at Worsley. After viewing the works, it immediately occurred to him, that if the coals on that part of the duke's estate could be brought to market in such a populous town as Manchester, and for the supply of the numerous works in its vicinity, the colliery, which, in the state it was at the time of his inspection, yielded little profit, would become extremely valuable. It is said, that he secluded himself altogether from company for two days, at the Bull inn at Manchester, to consider how this might be done by water-carriage, as that by land was very expensive, and, on account of the badness of the roads, very inconvenient, and almost impracticable. Having digested his scheme, he communicated it to the duke, who was no less struck with the proposition suggested by Mr. G. than the projector himself. Accordingly the work was soon after began. Mr. G.'s name has seldom occurred in connection with this very important and lucrative undertaking; and as he preceded Mr. Brindley in this business, of which we have ample and satisfactory evidence, we thought that justice required a candid and impartial statement of the case. Mr. G. was so fortunate, in the prosecution of this work, as to find lime upon the duke's estate, which must otherwise have been brought by land from Buxton, at the distance of near 30 miles; and in a work of this great extent, this was no inconsiderable saving. The tunnel was entirely executed, as well as planned, by Mr. G.; who, being acquainted with Mr. Brindley as a neighbour, and knowing him to be a very ingenious and excellent mill-wright, engaged his assistance in the conduct and completion of this arduous undertaking, and introduced him to the duke for this purpose. The duke was so well satisfied with his agent and projector, that at first they lived together for two or three months in the year, and for several of the last years of Mr. Gilbert's life, he spent half his time with him. In June, 1757, he removed with his family to Worsley, that he might, with greater convenience, attend the prosecution of the business he had undertaken. As a farther evidence of the duke's regard for Mr. G. we may here add, that he gave his son, who was educated for the church, the second best preferment at his disposal, to the amount of about 1200*l.* per annum. We might mention many other concerns in which Mr. G. was engaged, and in which he had an opportunity of manifesting his skill and judgment, in the conduct of canals, mines, and other improvements relating to rural economy. We shall merely add, that he is said to have been the first person who suggested the use of gun-powder in obtaining rock-salt. Mr. G. was probably so modest and unassuming, that he did not, during his life-time, lay claim to the honour which belonged to him, with respect to the duke of Bridgewater's canals and collieries; and we have introduced his name into the Cyclopædia, in order to do him justice, without meaning to detract from the merit of his coadjutor and successor, Mr. Brindley, to whom we have already paid ample and deserved respect under his biographical article. Mr. Gilbert's general character commanded the esteem of all who knew him; and his death, even after a prolonged life of about 73 years, which happened at Worsley, on the 4th of August, 1797, was, without doubt, regretted by his friends, and especially by the noble duke, who was in the house at the time.

Gilding

GILDING, or GUILDING, the art, or act, of ſpreading or covering certain ſubſtances with gold, either in leaf or powder, or in amalgam with quickſilver. See an account of theſe preparations of gold under GOLD.

The art of gilding was not unknown among the ancients, though it never arrived among them at the perfection to which the moderns have carried it. For this purpoſe the gold was beat into plates, with which the walls of apartments, diſhes, and other veſſels were covered. In early ages theſe plates were thick, ſo that this mode of gilding was very expenſive. (See the proceſs employed for gilding, in this manner, the horns of the ram brought by Neſtor, as an offering to Minerva, in Homer's Odyſſey, l. iii. v. 492.) In proceſs of time, however, the expence was much leſſened, becauſe the art was diſcovered of making theſe plates thinner, and of laying them on with a ſize.

Pliny aſſures us, that the firſt gilding ſeen at Rome was after the deſtruction of Carthage, under the cenſorſhip of Lucius Mummius, when they began to gild the ceilings of their temples and palaces; the Capitol being the firſt place on which this enrichment was beſtowed. But he adds, that luxury advanced on them ſo haſtily, that in a little time you might ſee all, even private and poor perſons, gild the very walls, vaults, &c. of their houſes. "When we cover our houſes with gold," ſays Seneca, (Epiſt. 115.) "what elſe do we than rejoice in deception? for we know, that coarſe wood is concealed under that gold." We need not doubt but that they had the ſame method with us, of beating gold, and reducing it into leaves; though, it ſhould ſeem, they did not carry it to the ſame height; if it be true, which Pliny relates, that they only made ſeven hundred and fifty leaves, four fingers ſquare, of a whole ounce. Indeed, he adds, that they could make more; that the thickeſt were called *bracteæ Prænestinæ*, on account of a ſtatue of the goddeſs Fortune at Præneſte, gilt with ſuch leaves; and that thoſe of the thinner ſort were called *bracteæ quæſtoriæ*.

The modern gilders alſo make uſe of gold leaves of divers thickneſſes; but there are ſome ſo fine, that a thouſand do not weigh above four or five drachms. The thickeſt leaves are uſed for gilding on iron, and other metals; and the thinneſt on wood. But we have another advantage above the ancients, in the manner of uſing and applying the gold: the ſecret of painting in oil, diſcovered of late ages, furniſhes us with means of gilding works that ſhall endure all the injuries of time and weather, which to the ancients was impracticable. They had no way to lay the gold on bodies that would not endure the fire but with whites of eggs, or ſize; neither of which will endure the water: ſo that they could only gild ſuch places as were ſheltered from the moiſture of the weather.

The Greeks called the compoſition on which they applied their gilding on wood, *leucophæum*, or *leucophorum*;

which is defcribed as a fort of glutinous compound earth, ferving, in all probability, to make the gold ftick, and bear polifhing. But as to the particulars of this earth, its colour, ingredients, &c. the antiquaries and naturalifts are not agreed.

There are feveral methods of gilding in ufe among us: viz. *gilding on an oily fize; gilding on a water fize; gilding by the fire*, which is peculiar to metals; *gilding of books, &c.*

We may diftinguifh, in general, two kinds of gilding, one with, and the other without, the application of heat. The firft method is practifed on thofe fubftances, fuch as wood, paper, leather, filk, lacquered and japanned ware, &c. which would be injured, and even deftroyed at the temperature requifite for the other fort of gilding, which is employed on fubftances that are not liable to alteration by expofure to a moderate heat, fuch as metals, and fometimes glafs and porcelain.

There are two methods of gilding on wood, *viz.* oil-gilding, and burnifhed gilding.

GILDING *in oil, or an oily fize*, is performed by cementing the gold to the ground by means of fat oil. Linfeed oil may be prepared for this purpofe, by putting fuch a quantity of it into a broad veffel as may cover the bottom about an inch deep, and adding to it as much water as will rife fix inches or more above the bottom. Let the veffel be expofed to the fun and rain, and the contents be occafionally ftirred for five or fix weeks, till the oil appear of the confiftence of treacle. Then feparate the oil from the water, and place it in a long bottle, or feparating-funnel, ufed by the chemifts, in fuch heat as will render it perfectly fluid; pour off the clear part, and ftrain the remainder through a funnel, and the whole will be fit for ufe. The water helps to clear and bleach the oil, and improve it in other refpects.

In order to prepare the wood for gilding, it muft firft be covered or primed with two or three coatings of boiled linfeed oil and white lead, in order to fill up the pores, and conceal the irregularities of the furface, occafioned by the veins in the wood. If greater nicety and perfection in the work be required, the wood fhould be firft rubbed with fifh-fkin, and then with Dutch rufhes.

When the priming is dry, the next operation is that of fizing the work, or laying upon it, by means of a brufh, or a large pencil, a thin coat of gold fize; care being taken that the brufh or pencil be made to pafs into all the cavities and projecting parts, if the fubject be carved. This gold fize is prepared by grinding calcined red ochre with a due proportion of the fat, or thickeft drying oil that can be procured, (the older the better); and this fize, in order to fit it for working more freely, is to be mixed, previoufly to its being ufed, with a fmall quantity of oil of turpentine, till it acquires a proper confiftence. Sometimes the work is fized with fat oil, and the japanner's gold fize (fee GOLD *Size*), ground alfo with ochre. If a high degree of perfection be required, the work fhould be fized a fecond time, and fome add a third fizing, before the gold is laid on. In order to afcertain its fitnefs for this purpofe, it is touched with the finger; and if it feel fomewhat adhefive or clammy, or, as the gilders call it, "tacky," but not fo as to be brought off by the finger, it is in a fit ftate for gilding. But if it be fo clammy as to daub, or come off on being touched, it is not fufficiently dry; or, if it has no clamminefs or fticking quality, it is too dry, and muft be fized over again before it is gilt. When the gold fize is good, it will be fufficiently dry in about twelve hours for the application of the gold. In this procefs, when the furface is fufficiently large and plain to contain them, the gold leaves may be laid on entire, either by means of a fquirrel's tail, or immediately from the paper which originally contained them, which laft method, practifed by thofe who have acquired the neceffary dexterity, is the fimpleft and moft expeditious, as well as the beft, for the perfection of the work. The leaves, being laid on the proper parts of the work, muft be fettled to the ground, by gently compreffing thofe, which feem to want it, with the fquirrel's tail on a cotton ball; and if any part of the gold has flown off, or has been difplaced, fo as to leave any fpot uncovered, a piece of another leaf, of a correfponding fize and figure, muft be laid upon it. When the parts are too fmall to admit of laying on whole leaves, or when vacancies are left, after laying on whole leaves, which require to be covered with the flips or fragments of leaves, thofe that are to be ufed are turned from the paper upon a cufhion. (See GILDING *Cufhion* and CUSHION.) They are then cut into flips, of a proper fize, by a blunt pallet-knife (fee GILDING *Knife*); and each flip is taken up on the point of a fine brufh, or by an inftrument called the "tip," (fee GILDING *Tip*,) which, being moiftened by breathing upon it, will take up the leaves, or any fragments of them from the cufhion. When thefe are thus applied to the parts of the work that were to be covered, they are gently preffed down by the cotton ball, till they lie every where evenly upon the ground; and the gold will immediately adhere to the fticky furface of the fize. Where the work is very hollow, and fmall pieces are wanted to cover parts that lie deep, they may be taken up, by the tip already mentioned, or the point of a fitch pencil, firft breathed upon, and thus conveyed to, and fettled in, their proper places. The whole of the work, being thus covered, fhould be fuffered to remain till it be dry, and it may then be brufhed over by a camel's hair pencil, or foft hog's hair brufh, in order to clear away any loofe particles of the gold leaf. If, after brufhing, any defective parts appear, fuch parts muft be again fized; and treated as before. The fquirrel's tail ufed in gilding is cut fhort, and fometimes fpread in the fan-fafhion, by means of a piece of wood formed like a pencil-ftick, but broad at both ends, and fplit to receive the tail; but it will equally ferve in its own form, when the hair is cut to a proper length. The cotton fhould alfo be formed into a ball, by tying it up in a piece of fine linen rag; for if it be ufed without the rag, the fibres adhere to the gold fize, and embarrafs the work.

This fort of gilding is chiefly ufed for domes, and the roofs of churches, courts, banqueting-houfes, &c. and for figures of plafter, lead, &c. that are to ftand expofed to the weather.

This oil-gilding is the moft fimple and eafy, leaft expenfive, and moft durable, as it will not be readily injured when expofed to the open air; and it may be alfo cleaned with a little warm water and a foft brufh; but, as it cannot be burnifhed, it wants the high luftre which is produced by the method we fhall next defcribe.

GILDING, *Burnifhed*, or *in Diftemper*, or *on Water-fize*, is that kind of gilding which is generally ufed for picture frames, mouldings, ftucco, and fuch wooden works as are fheltered from the weather, and not fubject to dampnefs. In order to prepare the wood for this fort of gilding, thofe parts that admit of it fhould be firft well rubbed with fifh-fkin, and then with Dutch rufhes. It fhould then be carefully covered with ftrong fize, made of fhreds, &c. of white leather, fuch as that ufed by glovers, or clippings of parchment boiled in water, in the proportion of about a pound of

the ſhreds or clippings, to ſix quarts of water, to the conſiſtence of a jelly, and then ſtrained through flannel while hot. When this coating is dry, eight or ten more muſt be applied, conſiſting of the ſame ſize, mixed with fine plaſter of Paris, or waſhed chalk, or powdered whiting; which mixture muſt be made by melting the ſize, aad ſtrewing the whiting, &c. gradually into it, ſtirring them well together, that they may be thoroughly incorporated. This is laid on with a ſtiff bruſh, and oftener or ſeldomer repeated, according to the nature of the work; for pieces of ſculpture, ſeven or eight layers ſuffice: for flat, or ſmooth works, they uſe ten or twelve. In the latter caſe they are applied by drawing the bruſh or pencil over the work: in the former, by dabbing it ſmartly on, that the ſize may enter all the dents of the carving.

After the laſt coat is laid on, and before it be quite dry, a bruſh pencil, dipped in water, ſhould be paſſed over the whole, to ſmooth it, and take away any inequalities that may have been formed; and when it is dry, the parts that admit of it ſhould be again bruſhed over till they are perfectly even. The work ſhould then be repaired, by freeing all the cavities from the priming: after which a water poliſh ſhould be given to the parts deſigned to be burniſhed, by rubbing them gently with a fine linen rag moiſtened with water.

When the whole work is become quite dry, a moderately thick layer muſt be applied, compoſed of ſize and bole, or yellow ochre. Doſſie, in the Handmaid to the Arts, gives the following recipe for the ſimpleſt compoſitions, uſed as the proper cement or gilding ſize in this kind of gilding: "Take any quantity of bole armeniac, and add ſome water to it, that it may ſoak till it grow ſoft. Levigate it then on the ſtone, but not with more water than will prevent its being of a ſtiff conſiſtence, and add to it a little purified ſuet or tallow ſcraped; and grind them together. When this is wanted for uſe, dilute it to the conſiſtence of cream, by parchment or glovers' ſize, mixed with double its quantity of water, and made warm. Some melt the ſuet or tallow, and mix it previouſly with five or ſix times its weight of chalk before it is put to the bole, to facilitate their commixture, to which in this wet ſtate they are ſomewhat repugnant. It is alſo ſometimes practiſed to put ſoap ſuds to the bole; which will contribute to its uniting with the tallow." (See Gold *Size*.) Let this compoſition be diluted with warm ſize mixed with two-thirds of water, and let it be ſpread with a bruſh over the whole of the work, and then ſuffered to dry; and then let the ſame mixture be applied in the ſame manner, at leaſt once more. After the laſt coat, it ſhould be rubbed in the parts to be burniſhed with a ſoft cloth, till it be perfectly even. Some add a little vermilion to the gilding ſize, and others colour the work, if carved, before it be laid on, with yellow and the glovers' ſize; to which a little vermilion, or red lead, ſhould be added. This laſt method is deſigned to give the appearance of gilding to the deeper and obſcure parts of the carving, where the gold cannot, or is not thought neceſſary to be laid on. But this practice is much diſuſed; and inſtead of it ſuch parts of the work are coloured after gilding; which operation is called "Matting."

The work being thus prepared ſhould be ſet in a poſition ſomewhat declining from the operator; who, having at hand a cup of clean water, and ſome hair pencils, moiſtens a part of the work, and then applies the gold leaf to the part ſo moiſtened in the manner already directed under the article *Oil*-Gilding, till it be completely covered, or till it be too dry to take the gold. This will immediately adhere on being preſſed with the cotton ball. The operator proceeds to moiſten the next part of the work, and apply the gold as before, repeating the operation till the whole is completed. If, in examining the work, any parts ſhould appear to need being repaired, they ſhould be moiſtened as before, and covered with the gold; but care ſhould be taken that no part be miſſed in the firſt operation, as it is not ſo eaſily mended as in oil-gilding: nor ſhould any drops of water be ſuffered to fall on the perfect part of the gilding, as the gold is very apt to turn black in this ſtate. The work being thus far gilt, when dry, and fit for the purpoſe, which it will uſually be in about twenty-four hours, remains, either to be burniſhed, or matted.

The proper period for this purpoſe can only be aſcertained by experience, and varies at different ſeaſons. The mode of diſtinguiſhing the fitneſs of the work to take the burniſh, is to try two or three particular parts at a diſtance from each other; and if theſe take the poliſh well, the whole may be concluded to be in a fit ſtate. But if the gold peel off, or be diſordered by the rubbing, the work muſt be deemed not ſufficiently dry; and if the gold bear the rubbing well, and yet receives the poliſh ſlowly, it is a proof of its being too dry, which ſhould be prevented by watching the proper time. For the work, when too dry, both requires much more labour to burniſh it, and fails at laſt of taking ſo fine a poliſh.

To burniſh it, is to ſmooth and poliſh it with a burniſher, which is uſually a dog's or wolf's tooth, or a blood-ſtone, an agate, or a pebble, or ſomething elſe very ſmooth, fitted in a handle for that purpoſe.

To mat, is to give it a light lick in the places not burniſhed, with a pencil dipped in ſize, wherein a little vermilion ſometimes has been mixed. This helps to preſerve it, and prevent its flawing, when handled. Or, it is to cover the hollow parts with a colour the neareſt in appearance to gold.

Some recommend for this purpoſe red lead, with a little vermilion ground with the white of an egg; but yellow ochre, or Dutch pink, with red lead, would better anſwer the end; or the *terra di Sienna*, very ſlightly burnt, or mixed with a little red lead, would have a much better effect, and be more durable than any other mixture ſo near the colour of gold in ſhade. Iſinglaſs ſize will likewiſe ſupply the place of the whites of eggs. This operation of matting ſuperſedes the neceſſity of yellowing, which is intended to give the appearance of gilding to the deeper and obſcure parts of the carving where the gold cannot, nor is thought neceſſary to be laid on.

The laſt thing is to apply a vermeil, or lacquer, in all the little lines and cavities; and to ſtop and amend any little faults with ſhell-gold.

The compoſition here called *vermeil*, is made of gum gutta, vermilion, and a little of ſome ruddy brown colour, ground together with Venice varniſh and oil of turpentine. Some gilders, in lieu of this, content themſelves with fine lacca, or dragon's-blood, with gum-water.

Sometimes, inſtead of burniſhing the gold, they burniſh the ground or compoſition laid on laſt before it; and content themſelves afterwards to waſh the part over with ſize. This method is chiefly practiſed for the hands, face, and other nudities in relievo; which, by this means, do not appear ſo very brilliant as the parts burniſhed; though much more ſo than the parts perfectly flat, or matted.

To gild a work, and yet preſerve white grounds, they apply a layer of Spaniſh white mixed with a weak fiſh-glue, on all the parts of the ground whereon the yellow, or the layer next under the gold, might run.

GILDING, *Japanners*, is performed by means of gold powder, or imitations of it, cemented to the ground by a kind of gold ſize: for the method of preparing which, see GOLD-*ſize*. This kind of gilding may be practiſed on almoſt any ſubſtance whatever, whether wood, metal, leather, or paper; nor is there any preparation neceſſary, beſides making the ſurface on which the ſize is to be laid, even, and perfectly clean. Then ſpread the japanner's ſize, mixed with a due proportion of oil of turpentine and vermilion, with a bruſh over the work, if the whole ſurface is to be gilt; or draw with it, by means of a pencil, the proper figure deſired, avoiding carefully any other parts; when it is almoſt dry, ſo as to be capable, by its clammineſs, of receiving the gold, dip a piece of waſh-leather wrapped round the finger in the gold powder, deſcribed under *Shell*-GOLD, and rub it lightly over the ſized work; or ſpread the powder with a ſoft camel's hair pencil; and with a camel's hair bruſh clear away the looſe powder, after the gilded ſurface is dry. When leaf gold is uſed, the method of ſizing muſt be the ſame as for the powders; but great care is neceſſary in laying them on, while the ſize is in a proper ſtate of dryneſs.

There is a *falſe kind* of gilding, in which a colour of gold is given by painting and varniſhes, without employing gold. Thus a very fine golden colour is given to braſs and to ſilver, by applying on theſe metals a gold coloured varniſh, which, being tranſparent, ſhews all the brilliancy of the metals underneath. Many ornaments of braſs are varniſhed in this manner, which is called *gold lacquering*, to diſtinguiſh them from thoſe that are really gilt. Silver leaves, thus varniſhed, are put upon leather, which is then called gilt leather; and many picture-frames have no other than this counterfeit gilding, which may be diſcovered by waſhing it with a little rectified ſpirit of wine; for the ſpirit will diſſolve the varniſh, and leave the ſilver leaf of its own whiteneſs. For plain picture frames, thick tin-foil may be uſed inſtead of ſilver; the tin leaf fixed on with glue is to be burniſhed, then poliſhed with emery and a fine linen cloth, and afterwards with putty applied in the ſame manner; being then lacquered over with the varniſh five or ſix times, it looks like burniſhed gold. (See LACQUERING.) Among the falſe gildings may alſo be reckoned thoſe which are made with thin leaves of copper or braſs, called Dutch leaf. In this manner are made all the kinds of what is called gilt paper. See GILDING *of Paper*.

GILDING *of Books*. There are various methods, with reſpect to the cement uſed, by which the edges of books or paper may be gilt. Strong gum-water or iſinglaſs ſize, or glover's-ſize may be employed; but as the gum-water, and weaker ſizes are apt to run beyond the edge, and thus cauſe the leaves to ſtick together, iſinglaſs, melted with the addition of ſome common proof ſpirit of wine, and a ſixth part of honey or ſugar-candy is much to be preferred; to which muſt be added a third of bole armeniac well powdered.

The following compoſition may be uſed for this purpoſe: Take bole armeniac, and ſugar-candy well powdered; mix them with the whites of eggs, beaten to an oily conſiſtence; and the cement will be fit for uſe. In applying any of theſe cements, the paper, in quires or in books, ſhould be well cut and poliſhed on the edges to be gilt; and well ſcrewed down by a preſs; in this ſtate it is to be bruſhed over, firſt with a little of the cement without the ſugar-candy or the bole; and when that is dry, either with the cement above given, or any other ſolution of gum or ſize with the proper proportion of the bole; after which it may be ſuffered to dry; and then water-poliſhed, by rubbing it with a fine linen rag ſlightly moiſtened. It is then fit for receiving the gold, provided it be moiſtened at that time; and the leaves may be then laid on, being cut according to the breadth which they are to cover, and preſſed cloſely down by a cotton ball; and after the gilding is thoroughly dry and firm, it may be poliſhed. See BOOK-*binding*, and GILDING *of Paper*.

GILDING *on china-ware*. The gold is very much valued on china-ware, and would be much more ſo, were it not that it is very liable to loſe its luſtre, and to rub off. The Chineſe have at preſent a method of preventing both theſe accidents, in a great meaſure, by means of a ſort of poliſhing, which they give it after it is laid on. They prepare for this purpoſe a fine piece of agate, which they poliſh on one ſurface in as perfect a manner as poſſible. With this they rub over the gold, as it lies on the porcelain, ſeveral times, when it firſt comes from the baking. This gives the gold a luſtre which it would not otherwiſe have, and fixes it down to the ware in ſuch a manner, that it cannot eaſily be got off. The principal miſchief to which gold thus laid on is ſubject, is the tarniſhing, or growing dull; this is remedied by the ſame ſort of means. They wet the veſſel, upon which they would revive the luſtre of the gold, in common clean water; and while it is wet, they rub it with the ſame poliſhed agate, adding a little fair water at times to keep it moiſt. If the gold has not been well laid on at firſt, this may poſſibly raiſe it or take it off in ſome places; but if it was originally put on with the help of this ſtone, as all the gold on porcelain now is, the rubbing it with it a ſecond time never gives it any ſcratches, but recovers its priſtine luſtre and beauty. It muſt be obſerved, that the rubbing with this ſtone muſt be all done one way, both in the firſt laying on the gold, and in the brightening of it up afterwards. This may ſerve as a method for us as well as the Chineſe, not only to recover the beauty of our tarniſhed gilt china-ware, but alſo to lay gold upon ſome of our home manufactures of this kind. Obſerv. ſur les Coutûmes de l'Aſie. See PORCELAIN.

GILDING *on enamel and glaſs*, is performed by burning or annealing, *i. e.* by producing a coheſion of the gold with the glaſs or enamel, by the intermediation of a flux, or by producing the like effect without any. In both theſe methods, the gold is made to adhere to the enamel or glaſs, in conſequence of the fuſion or approach to that ſtate, either of the flux uſed, or of the body of the enamel or glaſs itſelf, by which the gold is cemented to ſuch body. The flux, when any is uſed, may be either ſimple glaſs of borax, or any of the preparations of fluxes powdered (ſee FLUX); and the gold is uſed, either in the form of leaf gold, or in that of powder made mechanically, or by precipitation. (See GOLD *powder*.) When leaf gold is employed without any flux, the enamel or glaſs may be moiſtened with a very weak ſolution of gum arabic, and again dried. After being thus prepared, it ſhould be breathed upon till it becomes a little adheſive or ſticky, and then laid upon a ſufficient number of leaves of gold: when the gold is thus united to the enamel or glaſs by the cementing quality of the gum arabic, the work is ready for burning. If a flux be uſed, it ſhould be finely levigated, tempered with a very weak ſolution of gum arabic, and very thinly ſpread on the part of the work to be gilded: and when the gum water is almoſt dry, the leaf gold ſhould be laid on that part thus prepared for it, which is then in a ſtate proper for burning. In the preſent practice, the *aurum fulminans*, or precipitation of gold by alkaline ſalts, is made by thoſe who gild glaſs in the greateſt perfection; and the volatile alkali is employed for the precipitation by the chemiſt, who prepares it for this purpoſe. But when this kind of precipitate is choſen, the uſe of any flux muſt be avoided, and a very conſiderable degree of

heat applied. The manner of using the precipitate powders of gold, the *aurum fulminans* excepted, as well as the leaf gold, may be varied, by adding to it or omitting any flux; but in what way soever the powder is used, it is to be tempered with the oil of spike, and worked as the enamel colours; and the quantity of flux, when any is used, may be a third of the weight of the gold. In cases where the glass is very hard, or where the opportunity of a strong heat cannot be conveniently obtained, the expedient of using a flux in the following manner may be adopted with great advantage. Grind glass of borax to a fine powder; and having tempered it with oil of spike, lay it on the glass where the gilding is to be made; then burn the glass with a degree of heat, that will cause the borax to run; and when it is cold, apply the precipitate or leaf gold, and burn it again, as in other cases. After the work is burnt, if it be intended to be burnished, a proper lustre may be given to it, by rubbing the gilded part with a dog's tooth, or with a fine agate, or iron burnishers. Handmaid to the Arts, vol. i. p. 374, &c. See *Ruby* Glass.

Gold may be laid upon white earthen-ware or glass, by drawing your design, upon the vessel to be gilt, with japanners' gold size, moistening the size, as you find necessary, with oil of turpentine. Set the work in a clean place to dry for about an hour, and then place it so near the fire that you could but just bear the heat of it with your hand for a few seconds. Let it remain there till it feels quite tacky or clammy: then, having procured a cushion and some leaf-gold, cut it into slips of the proper size, and lay it on with a little cotton-wool. When the gold is all on, put the work into an oven to be baked for two or three hours.

Drinking glasses, with gilt edges, have been much admired in this country; the best of these are brought from Germany: those that are made in England, though equal in beauty to the foreign, being greatly inferior in the durability of the gilding. Dr Lewis made several experiments with a view of discovering this art; from which he concludes, that the gold is cemented to them by means of an intervening matter, which will adhere to glass so as not easily to be rubbed off. He tried mastich, and other resinous bodies rubbed warm on the glass, and several spirituous varnishes: but none of these were found to adhere sufficiently to the glass. He recommends to the trial of the artists in this way the harder oil varnishes: and glasses have been since prepared in England, probably on the principles which he has pointed out, with as durable gilding as those brought from Bohemia and Thuringia.

M. Zeigler, in a German translation of the "Commercium Philosophico-Technicum," describes a varnish for this purpose, with the method of using it, which appeared from his experiments to be the best. This varnish is prepared by boiling fine transparent amber, reduced to powder, in a brass vessel, to the cover of which a valve is fitted, with as much drying oil as will just cover it; and by diluting the above solution with four or five times its quantity of oil of turpentine. This varnish may be made to dry sooner, and acquires greater firmness by grinding it with a little white lead, or rather with a mixture of white lead and minium. It is to be applied very thin on the glass, and the gold leaf laid lightly on the varnished part; when the varnish is thoroughly hardened, the gold may be burnished, by laying a piece of smooth paper between the tooth or steel burnisher, and the gold. This gilding, M. Zeigler observes, is durable, and of a fine lustre. Com. Phil. Techn. p. 65, and 614.

Gilding *of figures and letters on paper*, and for the embellishment of manuscripts, is performed with shell-gold, tempered with gum-water; or the characters may be drawn with a milky solution of gum-ammoniacum made in water, and gold-leaf applied upon them when almost dry, or if all or any part of them is become quite dry, they may be again sufficiently moistened for receiving the gold by breathing on them. Letters raised from the surface of paper or parchment, in the manner of embossed work, such as are seen on ancient manuscripts, may be formed either by friction on a proper body with a solid piece of gold, or by leaf gold. The former method is practised by tempering pulverized crystal with strong gum-water, and with this paste forming the letters; when they are dry, they are rubbed with a piece of solid gold, as in polishing, and the letters will appear as if gilt with burnished gold. The letters are formed with an embossed figure, either of the separate letters, or of whole words, cut in steel; and each letter of these stamps, when they are used, is anointed evenly with a feather dipped in oil. Then fill these concave letters with the above paste, and strike the stamps in a perpendicular direction on the paper or vellum, laid over some sheets of paper.

When the embossed letters are formed with leaf gold, the following, or a similar composition must be used. Thicken beaten whites of eggs with as much vermilion as is necessary to give them the consistence of paste; use the stamps as before; and when the letters are dry, moisten them by a small pencil with strong gum-water: and when this is almost dry, cover the letters with leaf gold, pressing it close to every part of them with cotton or soft leather; after the gilding is dry, polish it with proper burnishers. Com. Phil. Techn. p. 64 and Handmaid to the Arts, p. 450, &c.

Gilding *of live-fish*, as craw-fish, carps, &c. may be performed without injuring the fish, by means of a cement; which Mr. Hooke, in his posthumous papers, directs to be prepared in the following manner: Put some Burgundy pitch into a new earthen pot, and warm the vessel till it receives so much of the pitch as will stick round it; then strew some finely powdered amber over the pitch when growing cold; add a mixture of three pounds of linseed oil, and one of oil of turpentine: cover the vessel, and boil the contained ingredients over a gentle fire; grind the mixture as it is wanted, with so much pumice-stone in fine powder as will reduce it to the consistence of paint. When the fish has been wiped dry, this mixture is spread upon it, and the gold leaf laid over it, and gently pressed down; after which, the fish may be immediately put into water, and the cement will harden, and be in no danger of falling off.

Gilding *on leather*. See Lacquering.

Gilding *of metals* may be done by cleaning the surface of the metal, and applying gold leaves to it, which, by means of rubbing with a polished blood-stone, and a certain degree of heat, are made to adhere perfectly well. In this manner silver leaf is fixed and burnished upon brass, in making French plate; and sometimes also gold leaf is burnished upon copper and upon iron. For this purpose, the metal, being previously polished and quite clean, is heated to about the temperature of melted lead, and covered with a double layer of gold leaf; then a blood-stone burnisher, applied gently at first, and gradually increasing the pressure, will cause the surfaces of gold and copper to touch each other in almost every point, and then adhere with a force proportioned to the completeness of the contact. The first layer being thus burnished, a second is made to adhere in the same manner, and sometimes a third, if the gilding is intended to be very solid. This method of gilding is tedious, and is subject to the almost impossibility of using a sufficient pressure without injuring the evenness of the gilded surface. In cases where these objections do not apply, there cannot be a more

effectual mode of gilding, as we perceive in the manufacture of gilt silver and copper wire. The bar, before it is committed to the wire-drawer, is plated with gold, by having several leaves of gold successively burnished down upon it, and being then subjected to the strong compression that takes place in wire-drawing, the gold and the other metal become so perfectly united, as to form, in a manner, one substance. See Gold *Wire*.

Some metals, and particularly silver, may be gilt in the following manner: dip pieces of linen in the solution of gold by aqua regia, and then burn them to ashes; rub these ashes on the surface of the silver, well cleansed from any unctuous matter, with a wet linen rag, dipped in salt water, and the particles of gold contained in them will thus be applied to the silver, and adhere to it, without the application of heat, or intervention of any other body. Burnish the silver with a blood-stone, till it acquires the colour of gold. Most gilt ornaments on fans, snuff-boxes, and other toys of much shew and little value, are nothing but silver gilt in this manner. Beckmann (Hist. of Inventions, vol. i.) suggests, that this method of gilding, sometimes called dry, and sometimes cold gilding, is a German invention; and that foreigners, at least the English, were first made acquainted with it about the end of the 17th century; for Robert Southwell describes it in the Phil. Transf. for 1698, and says, that it was known to very few goldsmiths in Germany. See Gilding *of Metals by the fire*.

Gilding *on paper, parchment*, and *vellum*. There are various methods used for this purpose, according to the several ends which the gilding is designed to answer. But for the most part, size, properly so called, and gum-water, are used as the cements, and the powders are more generally employed than the leaf gold. See the three first articles in Gilding.

The gilding proper to be used with water-colours may be either with the leaf-gold or powder; the leaf-gold may be laid on the designed ground by means either of gum-water, or isinglass size; observing, that the gum-water or size be of the weaker kind, and laid sparingly on the ground, and that proper time be allowed for it to be dry; and then the gold is applied to it, as in the articles above recited; and it may be polished, if necessary, by the dog's tooth, or other kind of burnisher. In gilding larger surfaces, it will be found useful to colour the ground with the gall-stone; and when colours are to be laid on the gilding, the gall of any beast brushed over the gold will adapt it for receiving the colours. When the gold powders are used along with paintings in water-colours, they are previously formed into shell-gold. The gilding proper for the coloured paper used in binding books, and for other such purposes, is performed much in the same manner: only that the gum-water and size may be much stronger, and that they are generally conveyed to the ground by means of a wooden plate or print, or by an engraved roller, which make an impression of the intended figure or design. In this kind of gilding, the japanner's gold-size may be also commodiously employed; and this should be always used when the embossed appearance is wanted in the greatest degree; and for this purpose it should be thickened with yellow ochre, mixed with as much red-lead as the proper working of the print will admit. Instead of the genuine leaf-gold, or gold powder, the German powder, formed of the leaves called Dutch gold, is commonly used in this kind of gilding. The edges of books or paper are gilt in the manner directed under the article Book-*binding* and Gilding *of books*.

Gilding *on Thread and Wire*. See Gold-*thread*, and Gold-*wire*.

Gilding *on Wood*. See the three first articles in Gilding.

Gilding *on Metals by the Fire*. There are two ways of gilding by fire; *viz*. that with liquid gold, and that with leaf gold. For the latter, see Gilding *of Metals*, supra.

The former, technically called "water-gilding," is performed with gold amalgamated with mercury, in the proportion of about six or eight parts of mercury to one of gold.

In order to this operation, they heat some pure quicksilver in a clean crucible, and, when it is nearly boiling, put about a sixth of its weight of fine gold in thin plates heated red-hot, and stir them gently about, till the gold be found melted and incorporated into a mass with the mercury. It is then allowed to cool; and when cold, it is to be put in a piece of soft leather; and by gradual pressure, the fluid part of the amalgam, consisting almost wholly of mercury, may be forced through the pores of the leather, while the gold, combined with about twice its weight of mercury, will remain behind, forming a yellowish silvery mass, of the consistence of soft butter. This, after having been bruised in a mortar, or shaken in a strong phial with repeated portions of salt and water, till the water ceases to be fouled by it, is fit for use, and may be kept for any length of time, without injury, in a corked phial. It is of indispensible importance that the materials of this amalgam should be perfectly pure; and therefore, the mercury employed in the preparation of it should be procured from the distillation of the red precipitate (nitrous red oxyd of mercury), either alone, or mixed with a little charcoal powder.

When silver is the metal to be gilt, it is prepared for the operation by soaking it in warm dilute muriatic acid, so that the surface may be rendered perfectly clean; it is next washed in clean water, which should be two or three times changed, in order to free it from the whole of the acid; and being afterwards dried, and made moderately warm, a little gold-amalgam, also warm, is to be evenly spread upon the silver, to which it will immediately adhere. In applying the amalgam, the operator uses a little knife, or a brush made of brass wire, for the purpose; and giving the work a gentle heat before the fire, he dabs or spreads the amalgam with the brush farther and more evenly upon it.

Thus far advanced, the metal is set over the fire, upon a grate, or in a sort of cage, under which is a pan of charcoal, yielding a heat just sufficient for evaporating the mercury; by which means the mercury is raised in fumes, and leaves the gold alone adhering to the work; in proportion as the mercury, evaporating and flying off, discovers places where gold is wanting, they take care to supply them, by adding new pieces of amalgam with the knife or brush.

If a thicker gilding be required than can result from so much of the amalgam as is applied at once, the metal, after the first quantity has left its gold fixed on the surface, has more of the amalgam spread upon it. After the evaporation of the mercury from this, another quantity may be applied in the same manner. When the mercury is evaporated, so that the surface becomes uniformly of a pale yellow colour, the metal is made to undergo other operations, by which its colour and lustre are heightened. For this purpose, it is first rubbed with a scratch brush, composed of fine brass wire, till its surface is made clean and smooth, but the pale yellow colour still remains; then it is covered over with a composition called gilding wax, and again exposed to the fire till the wax be burnt off; and this application is repeated till the gold appears of a proper colour. This gilding wax is composed of bees' wax, mixed with the following substances;

viz. red ochre, verdigris, green vitriol, or alum. Thus the colour of the gilding is heightened by a perfect dissipation of some mercury remaining after the former operation. The gilt surface is then covered over with a saline composition, consisting of equal quantities of nitre, sal ammoniac, green vitriol, and verdigris, finely powdered, and mixed up into a paste with water or urine; or, this is used instead of the gilding wax. The piece of metal thus covered is heated till the mixture smokes, and quenched in water or urine. This effect seems to be produced by the acid of nitre, which is disengaged by the vitriolic acid of the alum, or other vitriolic salt, during the exposure to heat, acting upon any particles of copper which may happen to lie on the gilded surface. If the colour of the gilding be not sufficiently heightened by the first application, a succeeding one will complete the desired effect. Some artists think they give an additional lustre to their gilt work, by dipping it in a liquor prepared by boiling some yellow materials, as sulphur, orpiment, or turmeric. The only advantage of this operation is, that a part of the yellow matter remains in some of the hollows of the carved work, in which the gilding is apt to be more imperfect, and to which it gives a rich and solid appearance.

Copper, and the alloys formed by its combinations with zinc, are gilded much in the same manner as silver; but their affinity for mercury being considerably less than that of silver, it is not easy to produce a complete adhesion of the amalgam of gold to the burnished surface of these metals by the same means, and with the same evenness as in the former case. Advantage is here taken of the nitric acid for facilitating the adhesion of the copper and mercury in the following manner. The piece of copper, *e. g.* a button, is first cleaned by steeping it in acid and subsequent washing, and it is then burnished in a lathe, or by other means: after this, it is dipped in a neutralized solution of nitrat of mercury, and in a few seconds, on account of the strong affinity of nitric acid for copper, the mercurial salt is decomposed. The copper takes the place of the mercury, and at the same time the mercury is deposited in the metallic state, on the surface of the copper, covering it entirely, and strongly adhering to it. The gold amalgam is now applied, and the rest of the process is the same with that which has been already described. Thus a given quantity of gold may be made to cover a larger surface than in any other way of gilding on metals; five grains of gold completely gilding both the upper and under surfaces of 144 copper buttons, each of them an inch in diameter. (Phil. Mag. ix. 20.)

Iron cannot be gilt by amalgamation, unless it be previously coated with copper, by dipping it in a solution of blue vitriol, or rubbed with the vitriol itself a little moistened. Iron may also receive a golden coat from a saturated solution of gold in aqua regia, mixed with spirit of wine; because the iron, having a greater affinity for the acid, precipitates the gold from it.

In the gilding of iron, or rather steel, by means of an amalgam, peculiar difficulties occur. If recourse be had to the method of simple burnishing down, the heat requisite for this purpose will, in many cases, bring the temper of the steel too low; on such occasions the mode already described of gilding copper is sometimes practised: that is, the parts of the steel to be gilded are pencilled over with nitrat of mercury, by which they are covered with a slightly adhering coating of mercury; then the amalgam is applied, and the gilding finished in the usual way. The objections to this process are, first, that a considerable heat is required, though inferior to that requisite for burnishing down; and, secondly, that even with all possible care, the gilding is apt to be rough and to scale off. A very considerable improvement on this method is to trace the figure of the gilding on the steel first of all with a brush charged with a strong solution of sulphated copper, in consequence of which a pretty thick plate of this metal is deposited on the steel to which it may be made to adhere with considerable firmness by means of the burnisher; thus the gilding is, in part, performed upon the copper.

A new method of gold gilding upon steel has lately been published (see Phil. Mag. xi. p. 144), possessing many advantages over the others, and capable of ultimately attaining a very high degree of perfection. This method depends upon the well-known fact, that if sulphuric ether and nitro-muriat of gold are mixed together, the ether will, by degrees, separate from the acid nearly the whole of the gold, and retain it for some time in solution in nearly a metallic state. If ether, thus charged with gold, is spread, by means of a pen or fine brush, on the surface of highly polished steel, the ether presently evaporates, leaving the gold behind in close contact with the steel, and the adhesion is considerably improved by the subsequent application of the burnisher. The dearness, and especially the rapid volatility of ether, are objections of some moment, but may be got over by using the best oil of turpentine instead of the ether, which has nearly the same efficacy in decomposing the nitro-muriat of gold, and is both cheaper, and not so very quickly evaporable.

On the subject of gilding by amalgamation, Dr. Lewis has the following remarks: "There are two principal inconveniencies in this business; one, that the workmen are exposed to the fumes of the mercury, and generally, sooner or later, have their health greatly impaired by them; the other, the loss of the mercury; for though part of it is said to be detained in the cavities made in the chimnies for that purpose, yet the greatest part of it is lost. From some trials I have made, it appeared that both these inconveniencies, particularly the first and most considerable one, might be in a good measure avoided, by means of a furnace of a due construction."

If the communication of a furnace with its chimney, instead of being over the fire, is made under the grate, the ash-pit door, or other apertures beneath the grate, closed, and the mouth of the furnace left open, the current of air, which otherwise would have entered beneath, enters now at the top, and passing down through the grate to the chimney, carries with it completely both the vapour of the fuel, and the fumes of such matters as are placed upon it. The back part of the furnace should be raised a little higher above the fire than the fore-part, and an iron plate laid over it, that the air may enter only at the front, where the workman stands, who will be thus effectually secured from the fumes, and from being incommoded by the heat, and at the same time have full liberty of introducing, inspecting, and removing the work.

If such a furnace is made of strong forged (not milled) iron plate, it will be sufficiently durable. The upper end of the chimney may reach above a foot and a half higher than the level of the fire; over this is to be placed a larger tube, leaving an interval of an inch, or more, all round between it and the chimney, and reaching to the height of ten or twelve feet; the higher the better. The external air, passing up between the chimney and the outer pipe, prevents the latter from being much heated, so that the mercurial fumes will condense against its sides into running quicksilver, which falling down to the bottom, is there catched in a hollow rim, formed by turning inwards a portion of the lower part, and conveyed by a pipe at one side into a proper receiver.

Another method is mentioned by authors of gilding upon metals, and also upon earthen-ware and glass; which is, to fuse gold with regulus of antimony, to pulverize this mass,

nd ſpread the powder upon the piece to be gilt; afterwards to expoſe it to ſuch a fire that the regulus may be evaporated while the gold remains fixed. But Dr. Lewis mentions the following inconveniencies to which this method is ſubject: the powder does not adhere to the piece, and cannot be equally ſpread; part of the gold is diſſipated along with the regulus; glaſs is fuſible with the heat neceſſary for the evaporation of regulus of antimony; and copper is liable to be corroded by the regulus, and to have its ſurface rendered uneven. Lewis's Com. Phil. Techn. p. 77, &c. p. 81. 88. and 108. Macquer's Dict. Chem. Eng. edit. 1777; and Aikin's Dict. of Chemiſtry, art. GILDING.

GILDING *Cuſhion*, is formed by a few folds of flannel, or a quantity of tow or wool, ſecured on a piece of wood of any ſize from eight to fourteen inches ſquare by a light covering of leather, and faſtened tight round the edges. The ſurface ſhould be perfectly flat and even, and it is uſually furniſhed with a handle. See CUSHION.

GILDING *Knife*, a ſlip of the hollow Spaniſh cane, cut up to a ſmooth and ſharp edge, with a good penknife: this cane knife cuts the gold leaf better than one of ſteel, as it is apt to ſtick to this laſt. This knife may in all reſpects be the ſame as thoſe uſed in painting, called "pallet knives;" the blade of which may be four or ſix inches long, and ſomewhat more than half an inch in breadth, with a proportionable handle.

GILDING *Pallet*, a flat piece of wood, about three inches long, and an inch broad, covered with a piece of fine woollen cloth.

By breathing upon this pallet, to moiſten the cloth a little, and then clapping it gently down upon the gold leaf, this may be raiſed from the cuſhion, and conveyed to the work to be gilded.

GILDING *Tip*, a tool made by faſtening the long hairs of a ſquirrel's tail between two cards, and uſed for taking up the gold leaf after it is cut, and applying it to the article to be gilded.

GILDING *Wax*. See GILDING of *Metals*.

Gin

GIN, formed probably by corruption from *engine*, in *Artillery* and *Mechanics*, is a machine for raiſing great weights, compoſed of three long legs, two of which are kept at a proper diſtance by means of two iron or wooden bars fixed to one of the legs by means of a bolt at one end, and by the other end to the other leg with a bolt and key, ſo that it may be put on or off at pleaſure. At three feet from the bottom is a roller moving in cheeks, that are faſtened to theſe poles by two iron bands and two iron bolts. The three legs of this machine are joined together with an iron bolt, about which they move; to this bolt is fixed an iron half ring to hook on the windlaſs, containing two braſs pullies. When the gin ſtands upright, and its legs are at a proper diſtance, one end of the cable is fixed to the dolphins of a gun or mortar with another windlaſs, containing likewiſe two braſs pullies, and the other paſſes through the pullies and round the roller, which is turned round by means of handſpikes paſſing through the holes in the ends of the roller: while a man holds the cable tight, the gin is raiſed to ſuch a height as to admit a carriage being put under it.

The gin is uſed in loading a timber-carriage with timber; it conſiſts of an acute triangular frame, in the lower part of which is a roll or windlaſs: at the apex is a ſet of pullies, and a hole to receive the top of a ſtrong pole, which is ſet up oppoſite the triangular frame, which by this means forms a ſort of tripod (or triangle, as it is commonly called among workmen) ſtanding acroſs a tree to be raiſed and loaded: the gin-rope is then reeved through a moveable block of pullies, faſtened by a chain to the tree, through that in the top of the gin and round the roll; and then, by means of hand-ſpikes or levers uſed to the roll, the tree is drawn up to a ſufficient height for the timber-carriage to be paſſed under it. Long trees are raiſed at one end firſt, and two of the wheels of the timber carriage are paſſed under them; when the other ends are raiſed in like manner, and the other two wheels (which are made to ſeparate for this purpoſe) are paſſed under them, and then are joined to the other wheels by the long adjuſtable pole with which the carriage is furniſhed. See TIMBER-*Carriage*.

An erect axis or drum, turned by the force of horſes coals than the horſe-gins then in uſe, and he accordingly erected for them a water-gin, the ſupply for which was raiſed by the ſteam-engines employed at the pits. Since the above period, ſmall ſteam-engines, called wimſeys in many places, have been applied to the winding of coals, and other minerals, and have already ſuperſeded all other modes of drawing at the large collieries; theſe ſeveral modes of drawing or winding we ſhall deſcribe particularly in the article WINDING-*Engine*.

GIN, in *Mining*, horſe-gin, or coal-gin, is a machine uſed for drawing buckets or corves of earth or minerals up a mine-ſhaft or tunnel-pipe of a canal: it conſiſts of a large vertical drum or barrel, on which a rope winds, which is conducted to pullies over the ſhaft; and uſually as one bucket or corve deſcends another aſcends. See the preceding article and *Mine* WINDING *Engine*.

GIN-*driver*, is the man or boy who attends the gin-horſe and turns him, when a full bucket or corve has arrived at the top of the mine-ſhaft.

Ginging

GINGING, in *Mining*, fteining or ftaining, fignifies the lining of a mine-fhaft with ftones or bricks for its fupport. Shallow fhafts, where the meafures are adapted to ftand, are funk firft, and the lining of them with ftone, or ginging, is begun from the bottom and carried up at once to the top: but in finking deep fhafts, after as great a depth is done at once as the nature of the meafures will permit, a further depth is funk in the bottom, beginning firft withinfide the ginging, and continuing the fhaft of that diminifhed diameter for 12 or 18 inches, according to the foundnefs of the meafures in that place, when it is gradually enlarged to the full fize as the finking proceeds, and funk fome yards lower, until upon reaching a bed of ftone, or as great a depth as is judged fafe, according to the nature of the finking, the ginging is begun, and carried up to where the diminifhing of the fhafts begins; when the fame is picked out to admit the fucceffive courfes of ftone or bricks, as high as is judged fafe, then the removal of the remainder of the fupport for the firft ginging is commenced, by cutting out a piece, wide enough to admit of one or two courfes of ftone or bricks, being built up like a pier, which is firmly keyed or underpinned to the ginging above by means of tile-fheds or thin flate if neceffary: a fimilar piece is then cut out and underpinned on the oppofite fide of the fhaft, and then another between each of thefe, and fo on, until the ginging of the lower and upper part is entirely joined all round the fhafts.

The fhaft is then deepened withinfide the laft ginging, and funk, firft narrow and then of its proper width, as far as is judged fafe, when a new ginging is begun, and carried up, and joined to that previoufly finifhed, as above defcribed. Solid ftone-beds or permanent rocks, which are met with in finking, are not ginged, but the fhaft is funk through fuch rocks, of the fame diameter as the infide of the ginging, which ftands upon their top and is pinned up beneath their bottoms.

Glasgow

GLASGOW, a very populous, handſome, and regularly built city, in the county of Lanark, in Scotland; ſituated on the north bank of the river Clyde, which is navigable for veſſels of 100 tons and upwards. In ancient times, and during the prevalence of the Roman Catholic religion, Glaſgow was chiefly diſtinguiſhed as an archiepiſcopal ſee, and was of courſe principally under the influence of the archbiſhop and his inferior clergy. Their power ſeems in thoſe days to have been civil as well as eccleſiaſtical, for the charters of the moſt ancient corporate bodies are held by this tenure, the civil magiſtrates being only noticed as of ſubordinate rank and authority, and the freedom fines, and other emoluments are expreſsly appropriated to eccleſiaſtical purpoſes. The revenue of the dioceſe of Glaſgow, if it may be eſtimated by the extent of lands ſubject to the payment of tythes, or (as they are called in Scotland) teinds, muſt have been very great; for thoſe burthens extended over almoſt the whole of the counties of Lanark, Renfrew, Dumbarton, Ayr, Dumfries, and Galloway, comprehending the whole ſouth-weſt diſtrict of Scotland, and perhaps a moiety of the moſt fertile land in the whole kingdom. Of this enormous revenue, ſince the reformation a ſmall part, but now of great value, has been appropriated for the ſupport of the univerſity of Glaſgow, ſome part for the payment of the parochial ſtipends, and a great part has reverted to the freeholders or their dependants, and theſe are conſtantly fluctuating as in other parts of the kingdom. The inſurrections and civil wars, which devaſtated Scotland ſubſequently to the reformation, and previous to the revolution, having diveſted Glaſgow of all that attraction which it had acquired as the archiepiſcopal and occaſionally as the royal reſidence, it appears to have been only remarkable as the occaſional ſcene of thoſe ſanguinary and ferocious conteſts for which the age was conſpicuous. It fell into the hands of the regent upon the defeat and flight of the unfortunate Mary Stewart at the battle of Langſide, two miles ſouth of the city. It was long afterwards battered and taken by Cromwell's army, and it was the refuge of the defeated party, after the battle of Bothwel bridge, fought between the regent (afterwards James II.) and the Covenanters. After the revolution it ſeems for many years to have been a place of little importance, poſſeſſing neither a ſufficient degree of wealth or refinement to render it conſpicuous for elegance or luxury, nor ſuch ſecurity or ſtrength as to make it deſirable or important as a military poſt. At the time of the Union with England, its whole population was eſtimated at only 14,000, a fact ſtated in the houſe of commons by Mr. ſecretary Dundas, (now lord Melville,) in one of the debates when the Iriſh Union was in contemplation. Subſequently to the Union, the riſe of Glaſgow in commercial importance, even under the ſucceſſive checks of the two civil wars in 1715 and 1745, of the vaſtly greater commercial embarraſſment, occaſioned by the ſuſpenſion of its colonial trade during the American conteſts, and all the ſubſequent hoſtilities produced by the French revolution, has been perhaps unequalled by any other place in the empire, or perhaps in the world. Its population, under the act of 1794, including its numerous ſuburbs, was returned at 94,000, and from the concealment which was practiſed from the idle fears of ignorant people, many of whom fooliſhly imagined that *cenſus* to be the precurſor of a military conſcription, that number is ſuppoſed to be at leaſt 30,000 ſhort of the actual amount.

Different hiſtories of Glaſgow have been publiſhed. Of theſe, one publiſhed many years ago by Mr. M'Ure, one of the city clerks, was much eſteemed, but is now conſidered as obſolete. Others have ſubſequently been written by Mr. Gibſon about 1774, and recently by Mr. Denholm, about 1796.

The limits of this article neceſſarily preclude the poſſibility of entering much into detail, nor would it be either amuſing or inſtructive to the general reader. We ſhall therefore inſert what remains concerning the preſent ſtate of

this great commercial and manufacturing city under the following general heads.

1. *Situation and general state of the adjacent country.*—Glasgow is situated on the north bank of the river Clyde, in N. lat. 55° 52', and W. long. from the meridian of Greenwich 4° 30'. The extreme length from E. to W., including two suburbs, is nearly two miles, and its breadth from the cathedral or high church to the river about one mile. The lower part of the city is nearly level, and the rest is upon the southern declivity of a hill. Perhaps no city or town in Europe is, upon the whole, more regularly planned; for all the principal streets are either parallel or at right angles to each other. The chief streets are better paved than those of London, and generally wider; all the front buildings are of fine free-stone, which is found in great abundance in the immediate neighbourhood. The granite, or *whin stone*, for paving the carriage ways, is also very plentiful close by the town. The houses are very large and lofty, being more generally upon the French plan, where every floor forms a separate lodging, accessible by a common staircase, than upon the English, where one person occupies the whole premises. The more wealthy inhabitants, however, have almost universally adopted the English taste in building. In the old part of the town it is indeed much to be regretted that there are too few public streets, so that an immense number of buildings are crowded together, many of which are accessible only by narrow passages, which are very ill calculated either for free circulation of air, admission of light, or domestic cleanliness. In the modern buildings these inconveniences are avoided, and whatever inconvenience may remain, must rather be attributed to the habits or negligence of the occupants, than to want of facilities on the part of the architects.

There are many very fine public buildings in Glasgow, the most prominent of which we shall very briefly enumerate.

Churches.—The cathedral or high church is perhaps the finest specimen in Scotland of that species of architecture, generally denominated Gothic. It was founded in the year 1123, and consecrated in the presence of king David I. in 1136. This building is more similar to that of Litchfield, than to any other of the English cathedrals, but it does not appear to have ever been completely finished, and certainly until lately little care has been used for its preservation. After the reformation it is said to have narrowly escaped destruction from the misguided zeal of the people, who confounded the building itself with the religious or superstitious ceremonies which they had exploded. It now contains two churches adapted to the Presbyterian form of worship, and the choir is used as a place of interment. The burying vaults, or cemetery, were formerly occupied as another place of worship for the barony or country parish of Glasgow; but lately a new church has been erected for this purpose at the opposite extremity of the church-yard. The great spire is very lofty, and in some degree resembles that of Salisbury. The church was dedicated to St. Mungo, or Kentigern, whose burying-place in one of the vaults is still shewn.

The remaining churches possess in general little claim to architectural encomium or description. They are six in number, *viz.* the college, St. Andrew's, North West, Iron, St. Enoch's, and St. George's.

St. Andrew's church is a handsome modern building, of Corinthian architecture, and is very similar in appearance to the church of St. Martin in the Fields, Westminster.

St. Enoch's and St. George's are also handsome modern buildings. Besides the established or parochial churches, there are many dissenting chapels and meeting houses, some of which are very handsome and commodious.

Prison.—This is a large and very strong building, situated in the centre of the city, adjoining to the Exchange. The lower part is occupied by the council-chambers, and rooms for the magistrates and the city clerks; the middle part of the building contains the close or lock-up rooms for those imprisoned upon criminal charges; and the two upper floors are allotted for the reception of civil debtors. The roofs are lofty, the apartments airy, and the building, upon the whole, commodious; but it is in contemplation to erect a new prison, with an enclosed space round it, where the prisoners may have the benefit of fresh air and exercise, from which they are at present precluded.

Bridewell.—This is a large building which serves as a place of confinement, or penitentiary house, for persons of depraved habits convicted of petty offences. It is very well regulated, and every means of encouragement afforded for reclaiming the prisoners from their vices, and promoting habits of industry. Many, at the period of their confinement, have thus acquired and received considerable sums, besides the expence of their subsistence, which is deducted from their earnings.

Town Hospital—for the reception of poor persons unable to maintain themselves. The expence of this establishment is defrayed by a tax or assessment on the inhabitants, and by the proceeds of the labour of those admitted, who are supplied with work suited to their respective abilities. The inmates are aged and infirm persons and destitute children: the latter are well educated, and when arrived at a proper age, the boys are apprenticed to trades and the girls sent to service. The economy of the house is superintended weekly by gentlemen who act in rotation. The whole is very well managed.

Royal Infirmary—a very fine modern building, from a plan of Messrs. Adams'. From 90 to 120 patients are generally under cure, but the house contains accommodation for a much larger number when required. It is supported by donations, legacies, and annual subscriptions; the funds at present amount to 10,000*l.* or 12,000*l.*, besides what has been annually expended; the annual disbursement is about 1800*l.* or 2000*l.*: the direction is vested in the lord provost, the dean of guild, convenor of the trades, professors of medicine and anatomy, president of the faculty of physicians, member for the city, and eighteen directors, ten of whom are elected by the contributors, and the others by various public bodies. The directors elected by public bodies are, one by the council, one by the merchants, one by the trades, one by the university, one by the ministers of Glasgow, and three by the faculty of physicians and surgeons. The medical assistance is afforded gratuitously.

Theatre Royal.—This superb house was erected a few years ago by voluntary subscriptions, upon transferable shares of 25*l.* each. The total cost was upwards of 15,000*l.* part of which still remains as a debt upon the property, the whole annual rent being appropriated for its gradual liquidation. The direction of the property is in sixteen directors, four of whom go out annually, in rotation, but may be re-elected. It is unquestionably the largest and most magnificent provincial theatre in Britain. The managers are merely lessees, and the lease is always given for a short period, seldom exceeding two or three years.

Concert and Assembly Rooms.—These rooms are also very splendid, and, like the theatre, were erected by voluntary subscription, upon transferable shares.

University.—The buildings of the university having been erected at various times, and in very different styles, cannot

be appreciated by any precise scale of architectural taste; but the whole has certainly an air of imposing grandeur, and is very well adapted in every respect to the purposes for which it is designed. It consists of four distinct courts, which communicate with each other, and is accessible from the high street by three gate-ways. Behind is a very large garden laid out in grass and shrubbery, with very fine walks; it is divided into three parts, of which one is appropriated as a botanical garden, another is open as a place of exercise and recreation for the students, and the third, in which the astronomical observatory is situated, is generally reserved as a place of retirement, for the professors, or of amusement for their families and friends.

The university of Glasgow was founded in the year 1450, by William Turnbull, bishop of the diocese, and then consisted of a chancellor, a dean of faculty, a principal, who was also professor of theology, and three professors of philosophy.

The professions and lectures are now as follow:

A lord chancellor; an office now honorary, and held for life.
Lord rector; also honorary—elective annually.
Dean of faculties; chosen by the professors or regents.
Principal; by the crown—present incumbent, Rev. Dr. Taylor.

Professions.			
Divinity,	appointed by the		university.
Church history,	-	-	crown.
Oriental languages,	-	-	university
Natural philosophy, or physic,	-	-	do.
Mathematics,	-	-	do.
Moral philosophy, or ethics,	-	-	do.
Logic,	-	-	do.
Greek,	-	-	do.
Humanity, or Latin,	-	-	do.
Civil law,	-	-	crown.
Medicine,	-	-	do.
Anatomy and botany,	-	-	do.
Practical astronomy,	-	-	do.

Lectures.	
Materia medica,	university.
Chemistry,	do.
Midwifery,	do.
Natural history,	do.
Elocution,	do.
Painting and drawing,	do.

The funds for the support of the university are in a very flourishing and prosperous state. Independently of the emoluments derived from the students, salaries and commodious houses are allotted to every professor, and these expences are defrayed from the funds at various times granted to the university: of these, the funds or tythes of the parish of Govan, form a very prominent part. The students of the five junior classes, *viz.* natural philosophy, moral philosophy, logic, Greek and Latin, are distinguished by wearing gowns of scarlet freeze; the students of the senior classes have no particular distinction of dress. The resident members of the university claim an exemption from all civil burthens and services, and generally from the jurisdiction of the city magistracy, but acknowledge that of the sheriff of the county, and of the supreme courts of Scotland.

The internal government of the university is vested in the principal and professors, who, in their juridical capacity, assume the title of regents. Their supreme court is a general assembly of the whole faculty, who, at a remote period, assumed the power even of capital punishment. The most severe sentence, however, which has been passed for many years, is that of expulsion, and even this has been very rarely exercised. An inferior court is the "Jurisdictio ordinaria," consisting of at least three regents, who determine offences against the general order and peace of the university, and punish by a pecuniary fine. Each professor also possesses the power of levying small fines in his own class for negligence, contumacy, or irregularity.

The number of students in the university was estimated at 500 thirty years ago, and this number is now greatly increased. The professors and students, when assembled for the election of a rector or any other general purpose, are divided into four nations, according to the places of their respective births, *viz.*

Glotiani—comprehending the natives of Clydesdale, and the adjacent districts of Scotland south of the Forth.

Transforthani—the natives of Scotland, on the north of the Forth.

Rothsiani—the natives of the west highlands of Scotland and of Ireland.

Loudoniani—those of the eastern districts of Scotland, of England, America, and the colonies. The votes of these nations are decided by a majority, and the majority of nations decides the question. In cases of parity the decision is in the regents.

The university of Glasgow has recently received a most valuable acquisition, by the bequest of the museum of the late Dr. William Hunter, of London. For the reception of this valuable legacy, a very handsome building has been erected, where it is now arranged. The museum consists of a valuable collection of paintings, chiefly original; a very fine selection of anatomical preparations; a cabinet of medals, and a fine library. The medals are accounted of such value, that the trustees of the British museum are said to have offered 25,000*l.* for them, besides furnishing such duplicates as they possessed, and defraying the expence of an application to parliament for an act, so far to dissolve the testator's will. This liberal offer, however, was declined.

The public library of the university is also a collection of uncommon value. It consists of upwards of 6000 volumes, and many very rare and valuable manuscripts. In the faculty hall are some valuable paintings, particularly one of the "Martyrdom of St. Catharine."

Among the celebrated literary characters, which have belonged to this seminary, the names of Dr. Cullen, Dr. Adam Smith, and the late professor Miller, are most recently conspicuous.

There are many other public buildings in Glasgow, of which it will be necessary to confine ourselves to very brief notices.

The *Trades-hall*—is a fine modern building from a plan of Messrs. Adams'. It is used for the general meetings of the fourteen incorporated trades, and is also occasionally occupied for concerts, balls, and other public amusements.

Merchants' Hall—is an old building, remarkable for nothing but the spire, which is a very fine one. It is used by the body to which it belongs, in the same manner as the Trades-hall.

Public Markets.—These are very commodious, and consist of square-paved courts, surrounded by the stalls where the meat is exposed to sale. No cattle are slaughtered here, and they are kept very clean and regularly inspected.

Barracks.—These are situated in a large area walled round, and consist of three very large buildings, one of which is appropriated for officers, and two for non-commissioned officers and privates. Their complement is 1072 men, but they will lodge, on emergency, 4 or 500 more.

Town-House—a fine old building adjoining to the prison. Only one hall is retained by the body corporate. The remainder contains the Tontine hotel, which was enlarged by subscription upon lives. The coffee-room is, perhaps, the largest and finest in Europe. It is supported by annual subscription, the subscribers amounting to upwards of 1000, who pay one pound five shillings each.

Bridges.—Three of these are of stone, and a fourth was actually built in the year 1795, when the river rising rapidly, in consequence of excessive rains, it was swept away in one night when very nearly finished. The arches being very flat, and the extremities not sufficiently secured, the accident was attributed, by professional persons, to the lateral pressure. Its place has since been supplied by a very handsome wooden bridge for foot passengers. The two bridges highest upon the river are plain, but very well built and paved. The lowest, or new bridge, is very finely executed, and is esteemed one of the most compleat specimens of this species of architecture in Britain.

Water-works.—The city of Glasgow, until lately, was supplied with water by pit-wells, and the water of these, although abundant in quantity, was of inferior quality both for washing and culinary purposes; as, besides other impurities, it holds in solution a considerable portion of marine acid, by which it is rendered hard and brackish. To remedy this inconvenience a public company was formed, who, at the expence of upwards of 60,000*l.*, brought water filtered from the river into every part of the city and suburbs by cast iron pipes, and from these pipes into every house, upon receiving a moderate annual payment from the proprietor or lessee. The capital necessary was raised by transferable shares of 50*l.* each. The rapidity with which those shares were bought induced others to form a separate establishment, and to raise water also from the river for the supply of the city. The first supply is drawn from the Clyde by two large steam engines, into a reservoir about two miles to the eastward of the town. From this reservoir it is filtered into another, and from thence conveyed by the pipes to a third immediately contiguous to the town. The whole lower part may be supplied from this without further forcing, but to supply the higher parts, a portion is again forced by another smaller engine to a cistern on a higher elevation, which commands every part above the former level.

The western water-work company draw their supply from the river, to cisterns situated on an eminence about one mile west of the town, where it is filtered, and conveyed by pipes, without requiring to be forced a second time. The inhabitants are left to their own free choice from which company to take their supply.

River Clyde.—The Clyde takes its rise about 60 miles to the south-east of Glasgow, in the same mountain which forms the sources of the Tweed and the Annan. Near the county town of Lanark, about 28 miles above Glasgow, it has three remarkable falls or cataracts, much visited by strangers. From Lanark to Glasgow it passes through a fine valley, richly wooded in many places, fertile and highly cultivated. From the new bridge of Glasgow, where it becomes navigable, until it terminates in St. George's, or the Irish channel, about 80 miles distant. About thirty years ago, Mr. Goldburn, an eminent engineer, was employed by the city of Glasgow to deepen the river, from the Broomilau or harbour, to the sea-port towns of Port Glasgow and Greenock, the former situated 21, and the latter 24 miles below the city. This he effected in a very judicious, although gradual and economical manner. The beneficial effects of his plan became soon apparent, have been, every successive year, improving, and must continue so for many years to come. He began by constructing, on either bank, projecting dykes, or jetties, into the river, at right angles, to the banks on either side, and placed at small distances from each other along the whole course of the navigation. These jetties intercept much of the earth and gravel washed down by successive floods, and thus supply the materials for ultimate contraction, without the expence of carriage. Besides this, a number of labourers are employed every summer season to drag the bottom of the river, and lodge the stuff which is withdrawn from the bottom between the projecting jetties. By the constant repetition of this simple process, a great part of the river is now contracted to less than one half of its original breadth, and has gained above four feet of additional depth. As the tonnage dues, the greater part of which is appropriated for this purpose, now exceed 6000l. *per annum*, these operations promise to be continued on a more extended scale than ever; and it is probable that in a few years vessels of large burthen may be brought up to the city. The largest hitherto brought up are about 130 tons, the depth of the channel being about nine feet at high water. The gentleman who now directs these improvements thinks, that in a few years this depth may be increased to 14 feet by the present plan.

It was lately proposed to improve the harbour by the construction of wet docks; but a difference of opinion having arisen respecting the controul under which these improvements were to be placed, the scheme has been suspended, but it is hoped not finally relinquished. The tonnage dues are one shilling *per* ton on merchandise, eight-pence on foreign produce, and four-pence on coals, brick, and other building materials. Manure, carried upon the river for the improvement of the adjacent country, is exempted from any tax.

The country stretching along the banks of the Clyde, for a number of miles, both above and below the city, is generally fertile, and, in most places, highly cultivated, and well enclosed. The parish of Govan, situated on the south bank of the river, is, perhaps, as highly improved as any district in Britain. Besides the natural fertility of the soil, this may be accounted for by the plentiful supply of coal, lime, and manure, which are supplied at cheap rates by water-carriage. It must also be greatly promoted by the circumstance of there being many landed proprietors, whose estates, although abundantly sufficient to maintain themselves and families in comfort and affluence under their personal superintendence, are not so large as to induce them to relinquish the profits and emoluments of cultivating their own property, which, of course, derives the united benefit of their personal skill, industry, and capital, besides that emulation which a laudable spirit of rivalry excites among them to surpass each other. The higher lands, both to the north and south, are considerably inferior, both in soil and cultivation, to those in the valley. In every direction round Glasgow, coal, lime, and iron-stone are found in great plenty, and give great advantages to the agricultural and manufacturing classes of the community.

The suburbs of Glasgow, which form the chief residences of the operative tradesmen, are the following:

Calton—a very populous village, immediately adjoining to the city on the south-east, and bordering on the *Green* of Glasgow. This village contains upwards of 20,000 inhabitants, with many manufactories, distilleries, &c. The green serves both for pasture and for the purposes of washing and bleaching There are a commodious washing-house, and fine walks for the recreation of the inhabitants. The dues of washing and pasture form part of the city revenue. The green contains upwards of 100 acres of ground.

Bridgetown—another suburb adjoining to the former, and similar in every respect.

Gorbals—a village on the opposite bank of the Clyde, governed by a chief magistrate, appointed by the council of Glasgow, and two resident baillies.

Anderston, Brownfield, Finnuston, and *Partick.*—These four villages lye to the west of Glasgow, on the north bank of the Clyde; they also are residences for operative tradesmen, and contain several extensive manufactories, *viz.* three large cotton mills, an extensive puntfield, and porter brewery, at Anderston; a large and flourishing glass-work at Finnuston, and the very large flour-mills belonging to the incorporation of bakers at Glasgow, at Partick, where are also the ruins of an ancient castle, formerly belonging to the archbishop.

Municipal Government of Glasgow.

This, as formerly remarked, in ancient times, was almost exclusively vested in the archbishop and chapter. Since the reformation, it underwent various changes during the successive alterations of government in Scotland at large. The last arrangement made by royal and parliamentary authority, was early in the 18th century, under William and Mary. It has since been modified by the authority of the Scottish convention of royal boroughs, who exercise this power without dispute. As at present constituted, the government of the city is vested in the lord provost, three merchants, and two trades baillies, the dean of guild, or president of the merchants, the convenor, or president of the trades, the city treasurer, and master of the public works, twelve counsellors from the merchants, and eleven from the incorporated trades, in all 33 counsellors. To this body the regulation of all the public business belongs; the lord provost being president, with the casting or deciding vote in cases of parity. The courts of justice within the city are the following:

1. The circuit court of justiciary, for the cognizance of criminal actions, which is held twice a year at Glasgow, for the counties of Lanark, Renfrew, and Dumbarton, generally before two of the lords commissioners, although any one of their number is competent. This court also decides appeals in civil causes from any of the inferior courts within the district.

2. The magistrates or town court. This court is held under the authority of the magistrates, assisted by the town clerks as legal assessors. The jurisdiction of this court extends to any amount subject to an appeal to the court of session.

3. The conscience court, for the decision of petty causes under twenty shillings, where the formality of an oath is dispensed with, or any written pleading.

4. The sitting magistrate also decides daily trifling claims under five shillings. The magistrates also exercise a criminal jurisdiction in petty crimes, and punish by imprisonment, pillory, and sometimes public whipping and banishment from the city.

5. The sheriff court, for the under-ward of Lanarkshire, is also held at Glasgow, before the sheriff substitute. His jurisdiction is equal to that of the magistrates, not only within the city, but the district. The decisions of this court are subject by appeal to the sheriff depute and to the court of session.

6. The justice of peace court also decides civil causes to a limited amount, and regulates disputes between masters and servants. The appeal from this court is to the quarter sessions, and finally to the court of sessions.

7. The small debt court is held by two or more justices, for the decision of causes under 10*l.* No professional lawyer is heard here, and the pleadings are verbal. They review their own decisions upon appeal, provided the sum decerned for be lodged with the clerk of court.

8. The commissary court is the remnant of the bishop's court. It decides for sums under 3*l.* 6*s.* 8*d.*, and also in cases of defamation. Its jurisdiction extends over all the ancient bishopric.

Police Establishment.—This establishment was constituted a few years ago under the authority of a special act of parliament. The commissioners named in the act are, the lord provost and baillies, and twenty-four commissioners elected by twenty-four wards, into which number the city is divided. The qualification of a commissioner, is the occupation of a *dwelling* house valued at 15*l.* or upwards of yearly rent; and of a voter, that of any house at 10*l.* or upwards. The business of this establishment is the lighting, cleaning, and guarding of the streets, and suppression of quarrels, riots, and other breaches of the public peace. For this purpose a master, or intendant of police officers, and watchmen are employed. A magistrate sits every morning at the police office to decide upon those who have been apprehended during the night. Where the charge is serious, he generally remits the cognizance of it to the town court, and punishes petty delinquencies by a small fine. The expence is defrayed by a tax on the valued rents of shops, warehouses, and dwelling houses, by fines levied in the course of the year by the sale of manure, from cleaning the streets, &c. The maximum of the tax is from 6*d.* to 1*s.* 3*d.* per pound of valued rent, but much less has been generally found sufficient. This institution has been always hitherto conducted with the most vigilant attention to economy, and is very popular even among those of the citizens, who strenuously opposed its original adoption.

Commerce and Manufactures.—The commercial importance of Glasgow only began to rise subsequently to the Union, and had attained no very important extent until the colonization of North America opened a wide field for the exportation of British commodities and the importation of American produce in return. Previous to the commencement of the American war in 1775, it had, however, engaged very extensively in the tobacco trade, for it appears that of 90,000 hhds. of tobacco imported into Britain in 1772, 49,000 hhds. were brought into the Clyde alone, and, in 1775, the importation was 57,143 hhds.

The operations of the war necessarily put a stop to this intercourse, to the great loss of the merchants engaged in it; many of whom have never been able to recover their debts. Upon the restoration of peace in 1783, the trade with America revived, and continued again in a flourishing state, until again recently suspended by the American non-intercourse act. In 1783, the registered vessels of the Clyde, were 386, and their tonnage 22,896, and in 1803, the number cleared outwards and inwards was as follows.

	At Greenock inwards,		
Foreign trade	406 ships,	53,546 tons,	5183 men.
Coast and fishing	730 vessels,	35,532	3147
	Outwards,		
Foreign trade	352 ships,	50,366 tons,	3673 men.
Coast and fishing	1016 vessels,	43,009	3326
	At port Glasgow inwards,		
Foreign trade	113 ships,	18,722 tons,	1081 men.
Coast and fishing	182 vessels,	7,226	551
	Outwards,		
Foreign trade	177 ships,	25,137 tons,	1692 men.
Coast and fishing	119 vessels,	7,202	424
Total	3095	238,790	17,077

From this note fome idea may be formed of the extent of the trade; but many of thefe veffels having probably made feveral voyages in the courfe of the year, it is not to be inferred that this number of veffels actually belongs or trades to the Clyde. The articles of exportation are chiefly Britifh manufactured goods, coals, fifh, &c. and the imports European, American, and colonial produce.

The city of Glafgow had alfo a very confiderable commercial intercourfe with the eaftern parts of the ifland, and with the northern ftates of Europe, until this was fufpended by the events of the war. This intercourfe is carried on by means of the Forth and Clyde canal, which interfects Scotland, and forms a junction between the eaftern and weftern feas, fome account of which has already been given under the article CANAL.

The manufactures of Glafgow had obtained no very great extent previous to the commencement of the American war, although they had been progreffively advancing during the whole courfe of the eighteenth century So far back as the reign of Charles II. indeed, fome attempts had been made to introduce the manufacture of foap, refining of fugar, and fome other branches, all of which proved abortive, and were difcontinued. The linen manufacture was the moft extenfive of the various attempts made, and the moft fuccefsful during the time that it lafted. It commenced about the year 1725, and continued progreffively advancing until it was almoft entirely fuperfeded by the cotton towards the clofe of the century. The cotton manufacture, which is now unqueftionably the ftaple trade of Glafgow, was profecuted to very fmall extent until after the year 1784, but when once introduced it advanced with unprecedented rapidity. It is impoffible to afcertain with any precifion its actual amount either in quantity or value at any given period for want of proper data. A computation in 1791 makes the number of looms employed 15,000, and the perfons who earned their fubfiftence by various parts of the proceffes of fpinning, weaving, bleaching, &c 135,000. It alfo eftimates the total value of the goods made yearly at 1,500,000*l.* The grounds of this calculation are not ftated, and little reliance can be placed on it, for the value of cotton goods has fluctuated as remarkably as the quantity has extended.

Two manufactories of earthen ware are carried on in Glafgow, but neither of them extenfively. Indeed a much greater quantity of Staffordfhire ware is ufed in the city itfelf than of the produce of either. Two or three rope works are alfo carried on, but to no great extent.

The printing of calicoes and other goods is, however, a very extenfive branch of the manufacture of Glafgow and its vicinity. The moft extenfive of thefe works, are thofe fituated upon the water of Leven, in Dumbartonfhire, about 18 miles diftant. The extenfion of the cotton trade has alfo greatly improved and enlarged the number of dye-works, and the manufactures of chemical preparations for the various proceffes of bleaching, dyeing, and printing. Thefe works are fituated in the vicinity of the city, chiefly on the banks of the river.

Of the chemical works carried on in Glafgow, fome are peculiar to it.

The manufacture of Cudbear was introduced by Mr. Mackintofh fo long ago as the year 1777. It is prepared from *rock-mofs*, and above 2000 gallons of human urine are daily confumed in the procefs. The cudbear gives a dark reddifh colour, and is ufed in the dyeing of leather, woollen ftuffs, &c. The procefs is kept profoundly fecret.

The difcharging of the Turkey red dye is alfo peculiar to Glafgow. This procefs is particularly defcribed under the article *Difcharging of* COLOUR.

The manufacture of the oxy-muriate of lime, in a dry form, for the purpofes of bleaching, &c. is alfo almoft peculiar to Glafgow. Its object is to decreafe the expence of bleaching by the fubftitution of lime for potafh. This article is made to great extent by Mr. Tennent the inventor.

Iron liquor, for the ufe of printers, is made here by various perfons, and large alum works are eftablifhed in the neighbourhood. Manufactures of red and white lead are alfo carried on.

Mifcellaneous Remarks.

It will appear that the city of Glafgow has undergone three remarkable changes. Its firft ftate was the refidence of a great archiepifcopal fee, and confequently it was for many ages entirely under clerical influence and controul. Its firft eminence as a commercial place arofe from its favourable fituation for commerce with the American and Weft Indian colonies, and through this traffick it made rapid advances in commercial importance during the whole courfe of the eighteenth century. One branch of this traffick being at leaft for the prefent fufpended, it now depends chiefly on the other, and upon its manufactures for fupport. From the facilities of acquiring a good education, the inhabitants of Glafgow have generally added a confiderable tafte for literary attainment even to their commercial habits, and this ftyle prevails, perhaps, in a degree fuperior to any other commercial place in Britain. The fyftem of education is, however, rapidly adapting itfelf to the modern purfuits of the inhabitants, and more pains are now taken to qualify the rifing generation for eminence in the counting-houfe than the clofet. However defirable a thorough knowledge of the principles of commercial economy, and the details of bufinefs may be in a commercial community, it is ftill to be hoped, that all the benefits arifing from intellectual attainment will not be deemed altogether nugatory, and confequently neglected. In every fituation of life, they are fources of rational and innocent amufement, and, in the viciffitudes to which commercial enterprife is peculiarly expofed, may often prove of real benefit and utility to the poffeffor.

The city of Glafgow returns a member to the Britifh parliament, conjunctly with the neighbouring burghs of Ruthuglen, Renfrew, and Dumbarton.

GLASGOW, *Port*, fituated on the river Clyde, about 22 miles below the city, is a handfome fmall town, and was projected by the magiftrates of Glafgow at the requeft of the merchants as a harbour for their fhips and veffels. It is faid that the firft plan was to improve the harbour of Dumbarton for this purpofe, but Dumbarton being a royal borough, the confent of its magiftrates became neceffary, and that when made, it was rejected by that body, who preferred the full enjoyment of their chartered privileges to the idea of finking into the mere fea-port of Glafgow, however much their wealth, revenue, population, and general profperity might be benefitted by fuch an union. If this were the cafe, it is one among the numberlefs inftances where comfort and profperity have been facrificed to a mere empty title. The harbour of port Glafgow is good but fhallow. The difadvantage of the bank, noticed in the article GREENOCK, is alfo much againft it as a haven. At port Glafgow there is a cuftom-houfe, where the general cuftoms of the Clyde are collected. There is here alfo a fine graving, or dry dock, built by the merchants of Glafgow long before that of Greenock was executed, and this circumftance alone brought many fhips up to this port which now come no further than Greenock. The fituation of port Glafgow is more pleafant than that of Greenock, the country more level, and better adapted for cultivation. In other refpects it is certainly

els calculated for the general purposes of maritime traffick than its rival, and therefore there is little probability of its extension. Indeed the shipping belonging to Glasgow is certainly on the decrease, the foreign merchants finding it more for their advantage to freight or charter vessels for any purpose than to build or buy vessels of their own, which both consume or sink a considerable portion of their capital, and may, from the many casualties and fluctuations to which commerce in this eventful age is exposed, prove rather burthens than advantages, while the mere ship-owner, if deprived of a freight or charter-party at one port, may with greater facility seek it at another, than the person with whom freight is only a secondary and inferior consideration.

Port Glasgow is governed by magistrates, appointed by the council of Glasgow, and some resident magistrates. Its exports and imports have been already given and compared with those of Greenock under the article GLASGOW, which indeed furnishes by far the greater part of the freight to and from both ports.

There are no manufactures here of any extent, excepting those which are to be found at almost all sea-port towns, *viz.* ship building and rope spinning. Both of these are carried on to a very considerable extent. A work was erected some years ago for refining of sugar, and also a small cotton-mill, but neither have ever been prosecuted to any great extent.

A plan has been formed, and its execution is now begun, which in time may produce a great effect, both on this town and Greenock. This plan has for its object the formation of a more direct communication between Glasgow and the west sea, than the present circuitous navigation of the Clyde, by means of a navigable canal to be carried from Glasgow to Ardrossan, near Irvine, which is about thirty miles farther down the river than the present ports. This canal was projected under the sanction and patronage of the present earl of Eglintoun, (lord Ardrossan of Great Britain,) a part of whose estates lie in that neighbourhood. Its objects are two-fold. First, to facilitate the ma[illegible] intercourse of Glasgow and Paisley with the New World, by a more direct channel and better harbour. Second, to improve the agricultural and internal state of Renfrewshire, and the northern district of Ayrshire, by affording means for the cheap conveyance of coal, lime, manure, and other heavy articles by means of the canal. Ardrossan is situated not more than thirty miles from Glasgow, by the line of the projected canal, and therefore the carriage of goods will not be more expensive or tedious than by the Clyde, for the canal being free from the constant interruptions arising from the operation of wind and tide upon the river, the time of arrival and departure may be depended upon at all seasons and in all weathers. A considerable sum has already been subscribed for the canal, and also for the harbour, and from the well-known energy and activity of his lordship's general character, there is no reason to doubt that every exertion for its speedy completion will be used.

It is natural to expect that every opposition will be given by those whose local interests will suffer by the success of this undertaking, and these comprehend many wealthy and powerful classes; but whilst some oppose, others will find it their interest to promote it, and the competition must be ultimately advantageous to the general body, however it may terminate as to those more immediately interested.

The other part of the plan is the formation of an excellent and secure harbour at Ardrossan, capable of receiving ships of large burthen, and this also is begun. The subscriptions for the two undertakings are conducted separately. The coast here is in some places reckoned dangerous during the prevalence of strong gales from the north-west, when vessels are making the land; but it is said that the bay of Lamlash, in Arran, will afford a safe and easy shelter within a few hours sail, when this may prove to be the case. The surveys, plans, and estimates for the canal and harbour of Ardrossan were made under the superintendance of Mr. Telford. It must be perfectly evident that this canal will in all events produce much benefit as it passes through the most populous and flourishing manufacturing district in Renfrewshire.

Glass

GLASS, in the general acceptation of this term among *Chemiſts*, denotes any ſubſtance or mixture, earthy, ſaline, or metallic, which is reduced by igneous fuſion to the ſhape of a hard, brittle, uniform maſs, which breaks with a conchoidal fracture, paſſing into ſplintery, and with a high degree of luſtre. Moſt glaſſes of this kind are alſo tranſparent. See VITRIFICATION.

GLASS, *Vitrum*, in a more reſtricted ſenſe, and as the term is commonly uſed in the *arts* and *manufactures*, ſignifies that tranſparent, ſolid, brittle, factitious ſubſtance, produced by the vitrification of ſiliceous earth with various ſalts and metallic oxyds, which is applicable to innumerable purpoſes of ornament and comfort, as well as of ſcientific inveſtigation and reſearch.

As to the antiquity of the term *glaſs*, Tacitus (Germ. c. 45.) and Pliny (l. xxxvii. c. 3.) inform us, that amber was called among the ancient Gauls or Germans by the name of *gleſum* or *gleſſum*; and from the ſimilarity which glaſs bore to amber with reſpect to tranſparency and brightneſs, it acquired a name, which was, in all probability, originally the ſame. The word *gleſum* denoted, without doubt, a ſhining or tranſparent ſubſtance, as *gleiſſen* expreſſes at preſent in the German language to ſhine; and our Engliſh word to *gliſten* is derived from it, and has nearly the ſame ſignification. Ducange ſays that ſome critics were of opinion, that the word *gleſum* itſelf implied glaſs rather than amber. The ancient Greeks, as it has been obſerved, applied the ſame term (ἤλεκτρον) both to glaſs and amber. The herb with which the Britons painted their bodies had alſo the name of *glaſtum*, perhaps from the ſhining appearance it might give to their ſkins, or poſſibly becauſe its aſhes might be uſed in the making of glaſs. The Latins called the ſame plant by the name of *vitrum*, the word they uſed to ſignify glaſs. (Cæſar. Bell. Gall l. v.)

We find frequent mention of this plant in ancient writers, particularly Cæſar, Vitruvius, Pliny, &c. who relate, that the ancient Britons painted or dyed their bodies with glaſtum, guadum, vitrum, &c. *i. e.* with the blue colour procured from this plant. And hence, as ſome have ſuppoſed, the factitious matter we are ſpeaking of, came to be called glaſs, as having always ſomewhat of this bluiſhneſs in it.

Merret (Not. in Ant. Neri de Art. Vitrar.) gives us the following characters or properties of glaſs, by which it is diſtinguiſhed from all other bodies, *viz.* 1. That it is an artificial concrete of ſalt and ſand, or ſtones. 2. Fuſible by a ſtrong fire. 3. When fuſed, tenacious and coherent. 4. It does not waſte or conſume in the fire. 5. When melted, it cleaves to iron. 6. Ductile, when red-hot, and faſhionable into any form, but not malleable; and capable of being blown into a hollowneſs, which no mineral is. (See DUCTILITY *of Glaſs*.) 7. Frangible when thin, without annealing. 8. Friable when cold. 9. Always diaphanous, whether hot or cold. 10. Flexible and elaſtic. 11. Diſſoluble by cold and moiſture. 12. Only capable of being graven, or cut with a

diamond or other hard ſtones, and emery. 13. Receives any colour or dye, both externally and internally. 14. Not diſſolvable by aquafortis, aqua-regia, or mercury. 15. Neither acid juices, nor any other matter, extract either colour, taſte, or any other quality, from it. 16. It admits of poliſhing. 17. Neither loſes of weight nor ſubſtance, by the longeſt and moſt frequent uſe. 18. Gives fuſion to other metals, and ſoftens them. 19. The moſt pliable thing in the world, and that which beſt retains the faſhion given it. 20. Not capable of being calcined. 21. An open glaſs, filled with water in the ſummer-time, will gather drops of water on the outſide; juſt ſo far as the water on the inſide reaches; and a man's breath blown upon it will manifeſtly moiſten it. 22. Little glaſs balls, filled with water, mercury, and other liquor, and thrown into the fire, as alſo drops of green glaſs broken, fly aſunder, with a loud noiſe. 23. Neither wine, beer, nor any other liquor, will make it muſty, nor change its colour, nor ruſt it. 24. It may be cemented as ſtones and metals. 25. A drinking-glaſs, partly filled with water, and rubbed on the brim with a wet finger, yields muſical notes, higher or lower, as the glaſs is more or leſs full; and this makes the liquor friſk and leap. See ARMONICA. For the electrical properties of glaſs, ſee ELECTRIC, &c.

GLASS, *origin and hiſtory of.* De Neri will have glaſs as ancient as Job; for that writer, chap xxviii. ver. 17. ſpeaking of wiſdom, ſays, "gold and glaſs cannot equal it."

This, we are to obſerve, is the reading of the Septuagint, Vulgate Latin, St. Jerom, Pineda, &c. for in the Engliſh verſion, inſtead of glaſs, we read *cryſtal;* and the ſame is done in the Chaldee, Arias Montanus, and the king of Spain's edition. In other verſions, &c. it is read *ſtone;* in others *beryl:* in the Italian, Spaniſh, French, High and Low Dutch, &c. *diamond;* in others, *carbuncle;* and in the Targum, *looking-glaſs.*

In effect, the original word is *zechuchith,* (זכוכית) which is derived from the root *zacac, to purify, cleanſe, ſhine, be white, tranſparent:* and the ſame word (Exod. xxx. 34.) is applied to frankincenſe; and rendered in the Septuagint *pellucid.* Hence the reaſon of ſo many different renderings; for the word ſignifying *beautiful* and *tranſparent,* in the general, the tranſlators were at liberty to apply it to whatever was valuable and tranſparent.

Herodotus (l. iii.) is, according to Dr. Falconer (Mancheſter Memoirs, vol. ii.), the moſt ancient writer (B. C. 440) who uſed the word ὑαλο-, which is generally underſtood to ſignify glaſs. But he evidently does not mean artificial glaſs, nor cryſtal, but, moſt probably, ſomewhat of the talcky kind, or lapis ſpecularis, which might readily be framed in ſuch a manner, as to form a convenient tranſparent caſe, ſuch as the ancient hiſtorian has deſcribed. Ariſtophanes (B. C. 400) ſeems to be the next writer who mentions glaſs: that poet, in his comedy called the Clouds, ſcene I. act. 2. uſes the word *hyalus,* ὑαλος, which is now ordinarily rendered glaſs. He there introduces Strepſiades teaching Socrates a new way to pay old debts, *viz.* "by placing a fair tranſparent ſtone, ſold by the druggiſts, from which the fire is ſtruck, between the ſun and the writing, and ſo melting away the letters thereof." This ſtone Socrates calls ὑαλος, which the Scholiaſt on Ariſtophanes derives from ὑειν, *to rain,* from the likeneſs it bears to ice, which is rain, or water congealed; though, it muſt be owned, the word ὑαλος is ambiguous, and ſignifies *cryſtal* as well as *glaſs:* and Gorræus obſerves, that the ancients had a kind of yellow amber, tranſparent as glaſs, called by ſome ὑαλο-.

Ariſtotle (B. C. 340) has two problems upon glaſs: the firſt, Why we ſee through it? The ſecond, Why it is not malleable? If theſe problems be Ariſtotle's, which the learned doubt very much, this would properly be the earlieſt teſtimony in favour of the antiquity of glaſs. Theophraſtus (B. C. 303) ſeems to have been well acquainted with glaſs; for he deſcribes it as having been made of the ſand of the river Belus, which was called ὑαλι-, to which he adds, that the commoneſt kinds are made with copper. The celebrated ſphere of Archimedes (B. C. 209), if it be truly deſcribed, is a remarkable inſtance of the perfection to which the art of making glaſs had been brought at that early period.

Lucian mentions large drinking glaſſes; and Plutarch, in his Sympoſiacon, ſays, that the fire of tamariſk wood is the fitteſt for making of glaſs.

Among the Latin writers, Lucretius is the firſt that takes notice of glaſs; "Niſi recta foramina tranant, qualia ſunt vitri;" lib. vi. v. 3. Dr. Merret, however, adds, that glaſs could not be unknown to the ancients, but that it muſt needs be as ancient as pottery itſelf, or the art of making bricks; for ſcarcely can a kiln of bricks be burnt, or a batch of pottery-ware be made, but ſome of the bricks and ware will be at leaſt ſuperficially turned to glaſs.

Hence, Ferrant. Imperatus, lib. xxv. cap. 7. "Glaſs, like the common kind, is found under ground, in places where great fires have been. Other glaſſes are found in round clods, like fire-ſtone, ſome brittle, others firm, &c. This foſſil glaſs is wrought by the Americans, and uſed inſtead of iron. And no doubt but vitrifications were more common in the ancient bricks than they are in ours; as they tempered their earth two years together, and burnt them better.

Virgil (B. C. 39) compares the clearneſs of the water of the Fucine lake to glaſs. Æneid, v. 759. Horace (B. C. 36) is more expreſs, and mentions glaſs in terms that ſhew its clearneſs and brightneſs to have been brought to great perfection. Carm. iii. Od. 2. Od. 13 In the time of Strabo, (A. D. 27) the manufacture of glaſs was undoubtedly well underſtood, and had become a conſiderable article. Seneca (A. D. 65) was not only well acquainted with glaſs as a ſubſtance, but alſo underſtood its magnifying powers when formed into a convex ſhape. Quæſt. Natur. lib. iii. vi.

Pliny (A. D 77) relates the manner of the diſcovery of glaſs. It was firſt made of ſand, according to that author, (Nat. Hiſt. l. xxxvi. c. 66, &c.) found in the river Belus, a ſmall river of Galilee, running from the foot of mount Carmel, out of the lake Cendevia. The part of the ſhore where the ſand was dug did not exceed 500 paces in extent, and had been uſed many ages before for the ſame purpoſe. The report of its diſcovery was, that a merchant ſhip, laden with nitre, or foſſil alkali, being driven upon the coaſt, and the crew going aſhore for proviſions, and dreſſing their victuals upon the ſhore, made uſe of ſome pieces of foſſil alkali to ſupport their kettles. By theſe means a vitrification of the ſand beneath the fire was produced, which afforded a hint for the manufacture. In proceſs of time the calx of iron, in form of the magnetical ſtone, came to be uſed along with the foſſil alkali, from an idea of its not only containing iron, but glaſs, in a liquid form. Clear pebbles, ſhells, and foſſil ſand, were alſo in many places employed for the ſame purpoſe. It is ſaid, that in India pieces of native cryſtal were uſed for that purpoſe; and on that account the Indian glaſs was preferred to any other. Pliny adds, that light and dry woods were uſed for the melting of glaſs; to which they added copper from the iſland of Cyprus, and the foſſil alkali, eſpecially that which is brought from the Eaſt Indies. The furnaces are kept burning without intermiſſion, that the copper may be melted with the glaſs, and out of this compound are made maſſes of a coarſe blackiſh colour. Theſe lumps or maſſes are

again melted, and tinged of the colour required. Some of these pieces are brought to the shape required by blowing with the breath; some are ground on a lathe, and others are embossed in the same manner as silver. Sidon was formerly famous for these manufactures, as specula or looking-glasses were first invented there; "siquidem etiam specula excogitaverat." Such is the ancient method of making glass, described by Pliny. In his time, it was made with sand found at the mouth of the river Vulturnus, upon the shore, for six miles between Cumæ and the Lucrine bay. This sand was very fine, and was ground to powder with a ball or sphere and a mill. It was then mixed with three parts of the fossil alkali, either by weight or measure; and being fused, was conveyed in a liquid state into other furnaces, where it was formed into a mass, called "ammonitrum," (or sand combined with the fossil alkali,) which mass was melted, and became then pure glass, and a mass of white vitrified matter. The same method of making it prevailed in Spain and Gaul. Glass was likewise made to imitate the lapis Obsidianus, a substance found by a person of the name of Obsidius, in Egypt and Ethiopia. This substance was of a very black colour, yet obscurely transparent, and often placed among specula in the walls of rooms, to reflect the shadow of objects. It was also used for the same purpose as gems (probably for engraving upon) and even for statues. Pliny mentions, that he saw solid statues of the emperor Augustus made of this material; and the same emperor dedicated four elephants made of the same substance in the temple of Concord. It seems to have been used from great antiquity; but in the time of Pliny the artificial imitation of it by glass was used instead of the native material; and he intimates that the black colour was produced by some colouring ingredient. The Romans had likewise an opaque red kind of glass, used for plates and dishes for the table, called "hæmatinon," one of various colours, called "myrrhinum," a white, a clear red, a blue, and indeed most other colours. Pliny observes, that no substance was more manageable in receiving colours, or being formed into shape, than glass. The perfectly clear glass, which bore the greatest resemblance to crystal, was, however, most valued. Nero gave for two cups, with two handles to each, and of no extraordinary size, 6000 sestertia, or nearly 50,000*l.* sterling. The inferior kinds were not uncommon, as Pliny informs us, that the use of glass cups had nearly superseded those of gold and silver. We shall here add, that Pliny knew the power of a hollow glass globe, filled with water, in concentrating the rays of light, so as to produce flame in any combustible substance upon which the focus fell; and he also mentions, that some surgeons in his time made use of it as a caustic for ulcers (l. xxxvii. c. 2.). He was likewise acquainted with the comparative hardness of gems and glass, as he observes, that the lapis Obsidianus would not scratch the true gems; and he also mentions (l. xxxvii. c. 13.), the counterfeiting of the latter, in his time, as a very lucrative art, and brought to great perfection. He also says, that glass might be cut or engraven upon by means of diamonds, which art is evidenced by the antique gems so frequently found. (See GEM.) Josephus, (l. ii. c. 10) mentions the sand of the river Belus, in Galilee, as fit for making glass.

The first time we hear of glass made among the Romans was in the reign of Tiberius, when Pliny relates that an artist had his house demolished for making glass malleable, or rather flexible; though Petronius Arbiter, and some others, assure us, that the emperor ordered the artist to be beheaded for his invention. In the time of Martial, (A.D. 84) glass was not only brought to great perfection, and in common use for drinking vessels, but was employed (as it seems) for bottles in which wine was kept, and likewise for pots to hold flowers. (Epig. 1. l. ii. 22. 40. l. iv. 86.) Galen (A.D. 143) frequently mentions glass in several parts of his works, and seems to have been well acquainted with the method of making it. Apuleius (A.D. 161) mentions the manufacture of glass cups, in his time, as highly wrought and carved in various ways, and of great value. Alexander Aphrodisiensis (A.D. 214) a Greek writer, and a commentator on Aristotle, has several remarks on glass respecting both its brittleness, especially on change of temperature, and its transparency.

The manufacturers of glass formed a company at Rome, and had a street assigned them, in the first region of the city, near the Porta Capena. A tax was laid upon them by Alexander Severus (A.D. 220) which subsisted in the time of Aurelian, and probably long after.

Mr. Nixon, in his observations on a plate of glass found at Herculaneum, which was destroyed A. D. 80, on which occasion Pliny lost his life, offers several probable conjectures as to the uses to which such plates might be applied.

Such plates, he supposes, might serve for *specula*, or looking-glasses; for Pliny, in speaking of Sidon, adds, "siquidem etiam specula excogitaverat;" the reflection of images from these ancient specula being effected by besmearing them behind, or tinging them through with some dark colour. (See MIRROR.) Another use in which they might be employed, was for adorning the walls of their apartments by way of wainscot, to which Pliny is supposed to refer by his *vitreæ cameræ* (lib. xxxvii. cap. 25. § 64.). Mr. Nixon farther conjectures, that these glass plates might be used for windows, as well as the laminæ of lapis specularis and phengites, which were improvements in luxury mentioned by Seneca, and introduced in his time, Ep. xc. However, there is no positive authority relating to the usage of glass windows earlier than the close of the third century: "Manifestius est," says Lactantius, "mentem esse, per oculos ea quæ sunt opposita, transpiciat, quasi per fenestras lucente vitro aut speculari lapide obductas." De Opificio Dei, cap. 5. See Phil. Trans. vol. l. art. 80. p. 601. vol. lii. art. 23. p. 123.

St. Jerome (A. D. 422) speaks of windows formed of glass, melted and cast into thin plates, as being used in his time. Paulus Silentiarius, a poet and historian of the 6th century (about A. D. 534), speaks of the brightness of the sun's rays, passing through the eastern windows of the church of St. Sophia, at Constantinople, which windows were covered with glass. Gregory of Tours (A. D. 571) laments the devastations frequently committed on the windows of the churches by the ravages of war. Johannes Philoponus, who lived about the year 630, or, as some say, a century earlier, not only speaks of glass, but of the panes being fastened in with plaster, much in the same way as at present.

If the opinion of Pennant, suggested under the article ANGUINUM *ovum*, be well founded, we have reason to believe, that, long before the conquest of Britain by the Romans, the art of manufacturing glass into such ornaments as beads and amulets was known among the Druids; and if the art was thus applied, it is not improbable to suppose, that it was employed for more important and useful purposes, as in the manufacture of glass vessels. Nor is it likely that the Britons derived this art from the Romans, who preferred silver and gold to glass for the composition of their drinking vessels. Besides, the glass that was commonly used by the Romans was of an inferior quality, and appears from some remains of it discovered at their stations

and houfes to have confifted of a thick, fometimes white, but moftly blue-green, metal.

According to venerable Bede, artificers fkilled in making glafs were brought over into England, in the year 674, by abbot Benedict, who were employed in glazing the church and monaftery of Weremouth. According to others, they were firft brought over by Wilfrid, or Wigfrid, bifhop of Worcefter, about the fame time, or, as others think, at a later period, A. D 726. Till this time the art of making glafs, or at leaft of applying it to this purpofe, was unknown in Britain: though glafs windows did not begin to be ufed before the year 1180: till this period they were very fcarce in private houfes, and confidered as a kind of luxury, and as marks of great magnificence. Italy had them firft, next France, from whence they came into England.

Leo Oftienfis (A. D. 760) fpeaks of the windows in his time being made with glafs-plates fixed in lead, and faftened together with iron. Anaftafius, an hiftorian of Rome, who was librarian to the pope, mentions, that in the pontificate of Leo III. who became pope about the year 800, painted glafs in windows was in ufe. The ftatutes of the church of Traguier, in Lower Britany, about the year 1156, fpeak of the windows of churches and chapels being ornamented with arms and military enfigns, painted upon the glafs in them. A charter of Richard II. of England, quoted by Rymer, (A. D. 1386), contains a paragraph in which is mentioned glafs, together with the manufacture of it for windows.

Venice, for many years, excelled all Europe in the finenefs of its glaffes; and in the thirteenth century, the Venetians were the only people who had the fecret of making cryftal looking-glaffes, and which they performed by blowing, much in the fame manner as a confiderable quantity of the common mirror-glafs is now manufactured. The great glafs-works were at Muran, or Murano, a village near the city, which furnifhed all Europe with the fineft and largeft glaffes.

The glafs manufacture was firft begun in England in 1557: the finer fort was made in the place called Crutched Friars, in London; the fine flint glafs, little inferior to that of Venice, was firft made in the Savoy-houfe, in the Strand, London. This manufacture appears to have been much improved in 1635, when it was carried on with fea-coal or pit-coal, inftead of wood, and a monopoly was granted to fir Robert Manfell, who was allowed to import the fine Venetian flint glaffes for drinking, the art of making which was not brought to perfection before the reign of William III. But the firft glafs plates, for looking-glaffes and coach windows, were made in 1673, at Lambeth, by the encouragement of the duke of Buckingham; who, in 1670, introduced the manufacture of fine glafs into England, by means of Venetian artifts, with amazing fuccefs. So that within a century paft, the French and Englifh have not only come up to, but even furpaffed, the Venetians, and we are now no longer fupplied from abroad.

The French made a confiderable improvement in the art of glafs, by the invention of a method to caft very large plates, till then unknown, and fcarce practifed yet by any but themfelves and the Englifh. That court applied itfelf with a laudable induftry to cultivate and improve the glafs manufacture. A company of glafs-men was eftablifhed by letters patent; and it was provided by an arret, not only that the working in glafs fhould not derogate any thing from nobility, but even that none but nobles fhould be allowed to work therein.

It was in the year 1665, under the miniftry of the great Colbert, that a company for "blown-mirror-glafs" was firft eftablifhed near Cherbourg, in Normandy, on the plan of the Venetian manufacture; but the beautiful art of cafting glafs was invented in France about the year 1688, by a perfon of the name of Abraham Thevart; and a company was foon eftablifhed for this branch of manufacture, which was firft carried on at Paris, and foon after removed to St. Gobin, where it ftill exifts in full activity, and undiminifhed reputation. An extenfive manufactory of this kind was firft eftablifhed among us near Prefcot in Lancafhire, about the year 1773, by a refpectable body of proprietors, who were incorporated by an act of parliament. They ftruggled for a confiderable time with difficulties; but being nobly relieved and encouraged by government, they have fucceeded in producing plates rivalling, if not furpaffing in fize, quality, or brilliancy, the moft celebrated continental manufactures. This company furnifhes, at Albion Place, London, plates of various dimenfions, from 12 to 144 inches in length, and from 10 to 72 inches in breadth; and alfo convex and concave mirrors, from 12 to 36 inches in diameter.

Glass, *Ingredients of.* The materials ufed in the compofition are fome faline fubftance and fome fort of filiceous earth.

1. The firft ingredient we fhall fpecify is filex or ftone. The beft is that which will melt, and which is white and tranfparent. It is this that gives confiftence and firmnefs to the glafs. This is found principally in Italy, being a fort of ftony fubftance called *tarfo:* the next is *puocoli*, or *cuogola*, a fort of pebbles found at the bottoms of rivers, and gathered for the Venetian manufacture out of the river Po, which are faid not to be inferior in whitenefs to alabafter.

Indeed, nothing makes finer and clearer glafs than common flint, diftinguifhed for this ufe by its clear tranfparent, black colour; this, before it is ufed, muft be heated redhot, and then immediately quenched in cold water. The heat whitens it, and the water caufes it to fplit in every direction, and facilitates the grinding of it. The charge of preparing this deters the glafs-men from ufing it. The rounded fragments of quartz, found in the beds of rivers among mountains, are fometimes ufed in foreign countries, being firft heated and ground to powder. Indeed, the preparation neceffary for ftone, in general, is to calcine, powder, and fearce it.

Ant Neri obferves, that all white tranfparent ftones, which will not burn to lime, are fit to make glafs; and that all ftones which will ftrike fire with fteel, are capable of being employed in making of glafs. But this latter rule, Dr. Merret obferves, does not hold univerfally. Where proper ftone cannot be had, fand is ufed; and it is now almoft the only kind of fubftance employed in the Britifh manufactures of glafs. The beft for this purpofe is that which is white, fmall, and fhining: examined by the microfcope, it appears to be fmall fragments of rock cryftal. For green glafs, that which is of a foft texture, and more gritty; it is to be well wafhed, which is all the preparation it needs. Our glafs-houfes are furnifhed with white fand for their cryftal glaffes from Lynn in Norfolk, and Maidftone in Kent, and from the weftern extremity of the Ifle of Wight; and with the coarfer, for green glafs, from Woolwich.

2. The fecond ingredient in the manufacture of glafs is an alkali, which is either foda, or pot-afh. It is always ufed at firft in the ftate of carbonat, though the carbonic acid flies off in the procefs. For the method of preparing each, fee Carbonat. Thefe alkalies are ufed in different degrees of purity according to the required quality of the glafs. The fineft fort of glafs requires the beft pearlafhes, purified by folution and evaporation, to drynefs; but for inferior glaffes coarfer alkalies, fuch as barilla,

wood-aſhes, and kelp, are employed. The aſhes of fern will alſo yield a ſalt, which will make excellent glaſs; and, moreover, the aſhes of the cods and ſtalks of beans, as alſo thoſe of coleworts, bramble buſh, millet-ſtalks, ruſhes, cyperuſes, and many other plants, may be uſed for the like purpoſe, and after the ſame manner.

There are other fluxes uſed for different kinds of glaſs, and for various purpoſes. Lime, in the form of chalk, is employed in the manufacture of glaſs; but this muſt be uſed only in ſmall proportions; for an exceſs would act powerfully on the ſides of the glaſs-pots, in conſequence of the eſcape of the carbonic acid from the chalk during the fuſion, and, beſides, it would render the glaſs opaque and milky in cooling, however clear it might be when hot. It is known by experience, that to 100 parts of ſilex and the requiſite quantity of alkali, no more than about ſix or ſeven parts of quick-lime, or chalk, can be added, without affecting the clearneſs of the glaſs. Borax is another very valuable flux; but its high price reſtricts the uſe of it to the fineſt kinds of glaſs, and to thoſe which are required to be free from ſpecks and bubbles. A very ſmall quantity of borax will correct any deficiency of ſtrength in the alkali.

Of the oxyds of lead, litharge and minium are found to be of ſingular uſe in the manufacture of glaſs. Litharge is a powerful flux, and imparts to glaſs the valuable qualities of greater denſity and greater power of refracting the rays of light, and of bearing ſudden changes from heat to cold, without being ſo liable to crack, and alſo greater tenacity when red-hot, ſo that it is more eaſily wrought. A conſiderable quantity of this oxyd is contained in the finer glaſſes; ſuch as the London flint glaſs, and that which is uſed for the table, for luſtres, for artificial gems, and for moſt optical purpoſes. Glaſs, however, that contains much lead, is extremely ſoft; and liable to be injured by hard bodies that come into contact with it; and it is alſo very fuſible. It is alſo liable to be corroded by very acrid liquors. Beſides, the uſe of lead renders it difficult ſo to unite the ſilex and alkali, that a piece of glaſs ſhall be throughout of uniform denſity. Another ingredient occaſionally uſed in glaſs is the black oxyd of mangeneſe, called "glaſs-ſoap," from its uſe in clearing the glaſs from any accidental foulneſs of colour, and more eſpecially from the green tinge, owing to the preſence of iron. Scheele and Bergman in their reſpective "Eſſays," have illuſtrated many curious circumſtances that attend the uſe of manganeſe in glaſſes, which are particularly detailed in Aikin's Dictionary. The manganeſe ſhould be choſen of a deep colour, and free from ſpecks, of a metalline appearance, or a lighter caſt: and it requires to be well calcined in a hot furnace, and then to undergo a thorough levigation. The effect of manganeſe in deſtroying the colours of glaſs is accounted for by M. Montamy, in his "Traité des Couleurs pour la Peinture en Email," in the following manner; the manganeſe deſtroys the green, olive, and blue colours of glaſs, by adding to them a purple tinge, and by the mixture producing a blackiſh brown colour; and as blackneſs is cauſed merely by an abſorption of the rays of light, the blackiſh tinge given to the glaſs by the mixture of colours, prevents the reflection of ſo many rays, and thus renders the glaſs leſs coloured than before. But the black produced by this ſubſtance ſuggeſts an obvious reaſon for uſing it very ſparingly in thoſe compoſitions of glaſs, which are required to be very tranſparent.

This purple colour may be corrected by charcoal, or in the glaſs-houſe, by thruſting a billet of wood down into the melted glaſs, which becomes charred by the intenſe heat, and cauſes the purple hue to vaniſh, with a ſlight effervеſcence of the glaſs, and eſcape of numerous ſmall air-bubbles. On the other hand, if a ſmall quantity of nitre is added to glaſs containing manganeſe, the purple colour is reſtored, or, if preſent, the diſcolouring effect of the charcoal is prevented, till the nitre becomes alkalized by the heat, and mixes with the other ingredients of the crucible. For the explanation of theſe phenomena, it is obſerved, that the oxyd of manganeſe gives the purple colour only ſo long as it remains in its higher ſtate of oxygenation; but when in contact with charcoal, the latter partially deoxygenates it, carbonic acid gas is formed, the cauſe of the bubbles obſerved on this occaſion, and the colour is now loſt. Nitre, on the other hand, is known to give out oxygen largely as ſoon as red-hot; and hence the manganeſe immediately retakes from this ſource the oxygen of which the charcoal had deprived it, and reſumes its colouring power. The other ſubſtances which take away the colour from glaſs, tinged red with manganeſe, are all the ſalts with the baſis of ſulphuric acid, ſuch as gypſum, ſulphat of ſoda, &c. and alſo ſulphur itſelf; likewiſe the oxyds of tin and iron, and of ſome other metals. Neverthleſs theſe ſubſtances have this power only when in contact with charcoal. The tinging power of manganeſe is perfectly deſtroyed by the addition of arſenic in any form. Thus, a mixture of oxyd of cobalt and oxyd of manganeſe, in the colouring ſtate, is of a dark purple; but on the addition of any arſeniat, or of white arſenic, the manganeſe is made inactive, and the proper cobalt-blue alone appears. Hence we perceive the neceſſity, when the red colour of manganeſe is wanted, to avoid any thing arſenical; and nitre is alſo generally added to keep the manganeſe always at the proper ſtate for imparting its colour. The oxyd of manganeſe is a very powerful flux for all earthy matters; and this, as well as lead, gives a great denſity to glaſs. The white oxyd of arſenic is another powerful and cheap flux in the making of glaſs; but it ſhould be very moderately uſed; for it takes a longer time to mix intimately with glaſs, and to allow it to be perfectly clear, than any other of the additions commonly employed. For want of this the glaſs has a milky hue, which increaſes with age; and when the arſenic is in exceſs, the glaſs becomes gradually ſoft, and is decompoſed. Beſides, glaſs of this kind is unſafe to be uſed in the form of drinking veſſels.

Nitre is alſo uſed, in ſmall quantities, in the manufacture of glaſs, and is deſigned to anſwer particular purpoſes, ſome of which we have already ſpecified. It not only ſerves to deſtroy the ſtrong tinge of yellow which is found in glaſs, prepared with lead as a flux; but in ſaline glaſs, it is requiſite, in a ſmaller proportion, to render it ſufficiently tranſparent, as in the caſe of looking-glaſſes, and other kinds of plates. For an account of Mr. Dollond's excellent contrivance for deſtroying the colours in the object-glaſſes of teleſcopes, &c. ſee Aberration.

With regard to the ſeveral fluxes above enumerated, we may obſerve, in general, that the more calx of lead, or other metallic earth, enters into the compoſition of any glaſs, ſo much the more fuſible, ſoft, coloured, and denſe this glaſs is, and reciprocally.

The colours given to glaſs by calces of lead are ſhades of yellow: on the other hand, glaſſes that contain only ſaline fluxes partake of the properties of ſalts; they are leſs heavy, leſs denſe, harder, whiter, more brilliant, and more brittle than the former; and glaſſes, containing both ſaline and metallic fluxes, do alſo partake of the properties of both theſe ſubſtances. Glaſſes too ſaline are eaſily ſuſceptible of alteration by the action of air and water; eſpecially thoſe in which alkalies prevail; and theſe are alſo liable to be injured

by acids. Those that contain too much borax and arsenic, though at first they appear very beautiful, quickly tarnish, and become opaque when exposed to air. By attending to these properties of different fluxes, phlogistic or saline, the artist may know how to adjust the proportions of these to sand, or powdered flints, for the various kinds of glass.

Glass, *proportion of ingredients in.* Different kinds of glass require different proportions; nor have these been precisely ascertained. We shall here, and in subsequent articles, state several of the most usual and approved mixtures that have been proposed. When silex is melted with twice its weight, or more, of dry carbonated alkali, either potash or soda, the result is a very soft deliquescent vitreous mass, always more or less opaque, strongly alkaline to the taste, and which, on exposure to moist air, or more speedily in water, totally dissolves into a clear liquor, which is a solution of silex in alkali. When the same alkali is equal to the silex in weight, or does not much exceed it, the glass is now transparent, but it is still soluble in water. It is not till the alkali is diminished to about one-half of the weight of the silex, that the glass becomes perfectly hard and insoluble in any corrosive liquors, (the fluoric acid excepted,) and, in short, acquires the character of a perfect glass. This proportion, therefore, of two parts of sand to one of alkali, is usually the datum on which the doses of the alkalies actually used are regulated. Thus, if common wood ashes (of which the alkaline part is reckoned at no more than 10 per cent.) are employed, 100lbs. of these would require no more than about 20lbs. of sand. If the best Spanish barilla, containing from 45 to 50 per cent. of carbonate of soda, be used, an equal weight of sand may be added; but if purified pearlash be taken, it will melt down perfectly twice its own weight of sand. But glasses composed merely of pure alkali and sand, require a very strong fire for their fusion, and are hard, harsh, and difficult to break: they are therefore never used alone. As one half the weight of the sand is reckoned an abundant allowance of alkali, it follows of course that when litharge, arsenic, borax, or any other fluxes are employed, the quantity of alkali will be proportionally diminished. The following proportions are extracted from Macquer's Chemical Dictionary. If a glass be required that is dense, fusible, and not saline, one part and a half of red lead or litharge may be mixed with one part of sand, and fused together: if equal parts of sand and of calx of lead be employed, a glass somewhat less dense and harder will be produced: if a glass be required of very little density, only saline fluxes must be employed. A glass of this kind may be composed of six parts of salt of tartar, or of potash, or of purified soda, mixed with eight parts of sand or of flints; or of four parts of any of the above-mentioned alkalies, mixed with two parts of nitre or of borax, and eight parts of vitrifiable earth. When a crystal glass is required, which shall be of an intermediate quality betwixt the metallic and saline glasses, it may be made from a mixture of one part of the above mentioned salts, one part of calx of lead, and two parts of sand or other vitrifiable earth. By varying the proportion of these ingredients, many different kinds of glasses may be produced, each of which may be good, if the quantity of each of the fluxes employed be proportionable to its vitrifying power.

Glass, *instruments for manufacturing.* These are subservient to two different purposes; *viz.* the levigation and mixture of the ingredients, and the fusion or vitrification of them. To the former class belong horse or hand-mills, mortars and pestles, flat stones and mullars, and searces or sieves. The other sort of utensils are furnaces, with the proper iron work, pots for containing the composition when put into the fire, and iron instruments for shifting the matter out of one into the other, in case of accidents; and for taking out small portions, in order to judge of the progress of the vitrification, and the qualities of the glass, &c. See the following articles. See also Glass-*house*, Furnace, and Glass-*pots*.

Glass, *fusion of.* When the ingredients are selected and duly proportioned, they are first calcined for a longer or shorter time, before they are put into the glass-pots. This operation is called "fritting," and is performed either in small furnaces adjoining to the proper glass-furnace, and heated by the same fuel after its chief force has been spent upon the glass-pots, or else in small furnaces or ovens constructed for this purpose. The uses of fritting are, to expel all moisture from the ingredients, by which the glass-pots would be endangered; to discharge part of the carbonic acid from the alkalies and chalk and thus to moderate the swelling in the glass-pots, and especially to cause an adhesion, or commencement of chemical union, between the alkali and silex, and metallic oxyds. This operation should be performed gradually, and carried to the point of semi-vitrification, in which the materials strongly adhere, and begin to become pasty, but are still opaque and not homogeneous. This operation serves also to destroy any carbonaceous matter. When the ingredients are sufficiently fritted, they are thrown with clean iron shovels through the side-opening of the furnace into the glass-pots, the fire having been previously raised to its greatest intensity, to prevent the furnace from being chilled and to save time. The pots are charged by two or three successive portions, the preceding one being thoroughly melted down before another portion is thrown in. When filled, the side-opening is closed up with wet clay, excepting a small hole for examining the work, which closure is pulled down when the glass is well refined and about to be worked off. As soon as the frit begins to feel the action of the fire in the glass-pots, which is immediately raised to its greatest pitch, it sinks down into a soft pasty state, increasing in tenacity till the fusion is complete. However, it is still opaque, from the rising of a white porous scum, known by the name of "sandiver," or "glass-gall." This substance appears to be a confused mass, consisting of all those salts contained in common alkalies, which readily melt at somewhat less than a glass-melting heat, and are either naturally soluble in a considerable degree, or have little, if any, affinity for silex, and not uniting in the composition of glass, but being lighter, rise to the top. Another heterogeneous substance, called "sandiver," is sometimes found at the bottom of the pots. This is quite different from the other, and seems to consist of a vitrified mass of arsenic and other impurities. But the scum, or proper "glass-gall," is almost entirely saline. When laded out and cooled, it forms a crumbly mass, sometimes white, at other times brown and fouled, and strongly saline, but not uniform in its composition, being sometimes merely salt, often very bitter, probably as common salt or sulphat of potash predominates. It is so volatile in a strong fire, that it is constantly dispersing from the surface of the glass in a dense vapour, which is first thick and black, afterwards whiter, and which corrodes the top of the crucible in its passage. With long continued fusion it would entirely escape in this state, if it were not scummed off with long ladles, and sold to metal refiners as a powerful flux. Abundance of this glass-gall is attended with one of the greatest inconveniences to the maker of glass, as it requires a considerable continuance of

ftrong heat to diffipate the whole of it, or otherwife the glafs would be full of bubbles, unfound, and having a cloudy gelatinous appearance. It is obferved, that glafs from potafh is more likely to fuffer from glafs-gall than the foda-glafs is, becaufe the potafh glaffes are harder, and do not run fo thin as the other, and the glafs-gall from them does not fo eafily diffipate in the fire.

During this procefs famples for examination are drawn out of the pots with an iron rod; and the glafs gradually becomes more and more flexible, denfe, and lefs brittle, and at laft the glafs-gall is entirely diffipated. Whilft the heat is continued, the glafs which was full of fpecks and bubbles is refined, and becomes beautifully clear, tranfparent, and colourlefs; and this procefs, which goes on from the ceffation of the vapour of the glafs-gall and its entire removal to the time when the glafs is altogether clear and free from bubbles, is called the "refining." After this the glafs is complete; but being too thin for working, it is cooled, by ftopping the draught of fire round the pot which contains it, and in cooling it thickens to a fit ftate for being wrought. For glafs that is caft into plates, lefs cooling is neceffary, as it is required to flow very thin and hot. On an average it takes about 48 hours for the fine flint glaffes, from the time when the pots are firft filled till the glafs is ready for working, in which ftate it is of a very full red colour, and poffeffes a fingular kind of confiftence and tenacity. It is juft foft enough to yield with eafe to any external impreffion, even to the force of the breath urged pretty ftrongly in the centre of the glowing mafs, and may be bent and fhaped in every poffible way; and fuch is its tenacity, that it extends uniformly without any cracks or fiffures; but when ftretched out to the utmoft, it forms a folid ftring, the diameter of which is conftantly decreafing till it feparates from the mafs in a thin capillary thread. It ftiffens as it cools, and becomes perfectly brittle and alfo tranfparent. As melted glafs adheres very feebly to polifhed metal, it is very eafily wrought with bright iron tools.

GLASS, *working or blowing round.*—Every kind of glafs, plate-glafs excepted, is formed from a hollow globe that has been produced by blowing. For this purpofe the operator takes his blowing-iron, which is a hollow tube, about four or five feet long, and dipping it in the melting-pot, turns it about there till the metal adheres to the iron like fome glutinous or clammy juice; he then holds it near the ground, fo that the mafs is extended by its own weight, and blows ftrongly into the tube. With his breath thus penetrating into the centre of the red-hot mafs, he enlarges it into an uniform hollow globe of the requifite thicknefs and bulk, keeping the force of his breath upon it for a few feconds till it ftiffens by cooling, and thus preventing its finking by the compreffion of the denfer external air. This globe, adhering by a neck to the iron rod, is formed by the dexterity of the workman, and by a variety of ingenious manœuvres into all the common utenfils. As a fpecimen of his art, we may inftance a common tumbler. The hollow globe already mentioned is taken off the iron rod by the following fimple procefs: An affiftant dips the end of a fhort folid iron rod into the glafs-pot, and, bringing out at its extremity fome of the melted glafs, thrufts it immediately againft the hollow of the globe at the part directly oppofite to the neck, to which it firmly unites, and thus the globe is cemented by the melted glafs to the fecond rod. The workman then wets a fmall piece of iron with his mouth, and lays it on the neck of the globe, which is extremely hot, and this, in a fecond or two, cracks it round; fo that with a flight pull it comes off and detaches the hollow rod, leaving the globe open at the neck, and transferred to the fecond rod at the oppofite fide. The open globe is again foftened by holding it a few feconds over the mouth of the glafs-pot, and is cut away from the open end to the form of a cup by iron fhears. The operator, when employed in fafhioning the globe, ufually fits upon a kind of arm-chair, with its arms floping forwards and covered with a flat fmooth iron-plate; and by laying the iron rod ftraight before him, refting on both the arms of his feat, and twirling it backwards and forwards, the hot glafs at the end is made to revolve like clay on a potter's lathe, and thus is opened, widened, or compreffed at pleafure by any fimple iron inftrument that is preffed againft it. The globular cup is thus extended eafily into a cylinder, or made into the fhape of a barrel, if this form be required, and is fmoothed up at the edges. In order to feparate it from the iron-rod, it is wetted as before at the point of attachment, and the tumbler drops off complete. This laft operation leaves that burr or roughnefs, with fharp fragments, which is feen at the bottom of all glafs-veffels, unlefs it be taken off by polifhing. The next operation is that of cooling the veffel very gradually, called "annealing." See *Annealing of* GLASS.

GLASS, *different kinds of.* The manufactured glafs now in ufe may be divided into three general kinds; white tranfparent glafs, coloured glafs, and common green or bottle-glafs. Of the firft kind, there is a great variety; as the flint glafs, as it is called with us, and the German cryftal glafs, which are applied to the fame ufes; the glafs for plates for mirrors or looking-glaffes; the glafs for windows and other lights; and the glafs for phials and fmall veffels. And thefe again differ in the fubftances employed as fluxes in forming them, as well as in the coarfenefs or finenefs of fuch as are ufed for their body. The flint and cryftal, mirror, and beft window glafs, not only require fuch purity in their fluxes, as may render it practicable to free the glafs perfectly from all colour: but for the fame reafon likewife, either the white Lynn fand, calcined flints, or white pebbles, fhould be ufed. The others do not demand the fame nicety in the choice of the materials; though the fecond kind of window glafs, and the beft kind of phial, will not be fo clear as they ought, if either too brown fand, or impure falts, be fuffered to enter into their compofition.

Of coloured glafs there is a great variety of forts, differing in their colour, or other properties, according to the occafions for which they are wanted. The differences in the latter kind depend on the accidental preparation and management of the artifts by whom they are manufactured.

GLASS, *Cryftal.* Foreigners ufe this term for our flint glafs, and for making it they give the following directions: Take of the whiteft tarfo, pounded fmall, and fearced as fine as flour, two hundred pounds; of the falt of polverine, a hundred and thirty pounds: mix them together, and put them into the furnace, called the *calcar*, firft heating it. For an hour keep a moderate fire, and keep ftirring the materials with a proper rake, that they may incorporate and calcine together; then increafe the fire for five hours; after which take out the matter; which, being now fufficiently calcined, is called frit. From the calcar put the frit in a dry place, and cover it up from the duft for three or four months.

Now, to make the glafs, or cryftal: Take of this cryftal frit, called alfo *bollito;* fet it in pots in the furnace, adding to it a due quantity of manganefe: when the two are fufed, caft the fluor into fair water, to clear it of the falt, called *fandiver;* which would otherwife make the cryftal obfcure and cloudy. This lotion muft be repeated again and again, as often as needful, till the cryftal be fully purged; or, this fcum may be taken off by means of proper ladles. Then fet

it to boil four, five, or six days; which done, see whether it have manganese enough; and if it be yet greenish, add more manganese, at discretion, by little and little at a time, taking care not to overdose it, because the manganese inclines it to a blackish hue. Then let the metal clarify, till it becomes of a clear and shining colour; which done, it is fit to be blown, or formed into vessels at pleasure.

Glass, *Flint*, as it is called in our country, is of the same general kind with that which in other places is called crystal glass. It has this name from being originally made with calcined flints, before the use of the white sand was understood; and retains the name though no flints are now used in the composition of it. This flint glass differs from the other, in having lead for its flux, and white sand for its body; whereas the fluxes used for the crystal glass are salts or arsenic, and the body consists of calcined flints, or white river pebbles, tarso, or such stones. This glass, on account of the quantity of litharge, which enters into its composition, is the heaviest, the most brilliant, the softest and most easy to work, and also the most expensive. It is that fine glass, of which the common and most valuable articles of white glass in domestic or ornamental use are manufactured; and besides, many optical instruments are made of this substance. To the white sand and lead a proper proportion of nitre is added, for the purposes specified in a former part of this general article, and also a small quantity of manganese, and in some works they use a proportionable quantity of arsenic to aid the fluxing ingredients. The most perfect kind of flint glass may be made by fusing with a very strong fire a hundred and twenty pounds of the white sand, fifty pounds of red lead, forty pounds of the best pearl-ashes, twenty pounds of nitre, and five ounces of manganese.

From others we have the following composition for glass of this kind, said to be of the best quality, *viz* 120 parts of fine clear white sand, 40 of pearl-ashes well purified, 35 of litharge or minium, 13 of nitre, and a small quantity of black oxyd of manganese.

The following composition for a fine crystal glass is given by Loysel; 100 pounds of white sand, 80 to 85 of red oxyd of lead, 35 to 40 of pearl-ash, 2 to 3 of nitre, and one ounce of manganese. The specific gravity of this glass, and of the common London flint-glass, is about 3.2.

Another composition of flint glass, which is said to come nearer to the kind now made, is the following: a hundred and twenty pounds of sand, fifty-four pounds of the best pearl-ashes, thirty-six pounds of red lead, twelve pounds of nitre, and six ounces of manganese. To either of these a pound or two of arsenic may be added, to increase the flux of the composition. A cheaper composition of flint glass may be made with a hundred and twenty pounds of white sand, thirty-five pounds of the best pearl-ashes, forty-pounds of red-lead, thirteen pounds of nitre, six pounds of arsenic, and four ounces of manganese; or, instead of the arsenic, may be substituted fifteen pounds of common salt; but this will be more brittle than the other. The cheapest composition for the worst kind of flint-glass, consists of a hundred and twenty pounds of white sand, thirty pounds of red-lead, twenty pounds of the best pearl-ashes, ten pounds of nitre, fifteen pounds of common salt, and six pounds of arsenic. The best German crystal glass is made of a hundred and twenty pounds of calcined flints, or white sand, seventy pounds of the best pearl-ashes, ten pounds of salt-petre, half a pound of arsenic, and five ounces of manganese. And a cheaper composition is formed of a hundred and twenty pounds of calcined flints, or white sand, forty-six pounds of pearl-ashes, seven pounds of nitre, six pounds of arsenic, and five ounces of manganese.

A glass, much harder than any prepared in the common way, may be made by means of borax in the following method: take four ounces of borax, and an ounce of fine sand; reduce both to a subtile powder, and melt them together in a large close crucible set in a wind-furnace, keeping up a strong fire for half an hour; then take out the crucible, and when cold break it, and there will be found at the bottom a pure hard glass, capable of cutting common glass like a diamond. This experiment, duly varied, may lead to several useful improvements in the arts of glass, enamels, and factitious gems, and shews an expeditious method of making glass, without any fixed alkali, which has been generally thought an essential ingredient in glass; and it is not yet known whether calcined crystal, or other substances, being added to this salt instead of sand, it might not make a glass approaching to the nature of a diamond. Shaw's Lectures, p. 426.

Glass, *Crown*, is the best sort of window-glass, and differs from the flint-glass in containing no lead, nor any metallic oxyd, except manganese, and sometimes oxyd of cobalt, in minute doses, not as a flux, but for correcting the natural colour. This glass is much harder and harsher to the touch than the flint-glass; but when well made it is a very beautiful article. It is compounded of sand, alkali, either potash or soda, the vegetable ashes that contain the alkali, and generally a small portion of lime. A small dose of arsenic is often added to facilitate the fusion. Zaffre, or the oxyd of cobalt, with ground flint, is often used to correct the dingy yellow of the inferior sort of crown-glass, and by adding the blue, natural to glass coloured with this oxyd, to convert the whole into a soft light green. One ounce of zaffre is sufficient for 1000lbs. But when the sand, alkali, and lime are very fine, and no other ingredients are used, no zaffre nor corrective of bad colour is required. A very fine glass of this kind may be made by 200 parts of pretty good soda, 300 of fine sand, 33 of lime, and from 250 to 300 of the ground fragments of glass. We had formerly in London two kinds of crown glass, distinguished by the places where they were wrought; *viz.* 1. *Ratcliff crown glass*, which is the best and clearest, and was first made at the Bear-garden, on the Bank-side Southwark, but since at Ratcliff: of this there are twenty-four tables to the case, the tables being of a circular form, about three feet six inches in diameter.

2. *Lambeth crown glass*, which is of a darker colour than the former, and more inclining to green. The following composition has been recommended for the best window or crown glass, *viz.* white sand, sixty pounds; of purified pearl-ashes, thirty pounds; of salt-petre, fifteen pounds; of borax, one pound; and of arsenic, half a pound. If the glass should prove yellow, manganese must be added. A cheaper composition for window glass consists of sixty pounds of white sand, twenty-five pounds of unpurified pearl-ashes, ten pounds of common salt, five pounds of nitre, two pounds of arsenic, and one ounce and a half of manganese. The common, or green window glass, is composed of sixty pounds of white sand, thirty pounds of unpurified pearl-ashes, ten pounds of common salt, two pounds of arsenic, and two ounces of manganese. But a cheaper composition for this purpose, consists of a hundred and twenty pounds of the cheapest white sand, thirty pounds of unpurified pearl-ashes, sixty pounds of wood-ashes well burnt and sifted, twenty pounds of common salt, and five pounds of arsenic.

The manufacture of the common window glass, though made by blowing, is conducted differently from that of the flint glass articles; as it is the object to produce a large, flat, very thin plate of glass, which is afterwards cut by the

glazier's diamond into the requisite shape. Without minutely detailing the several gradations of the process, it may be here mentioned, that the workman takes a very large mass of melted glass on his hollow iron rod, and by rolling it on an iron plate and swinging it backwards and forwards, causes it to lengthen, by its own weight, into a cylinder, which is made hollow and brought to the required thinness, by blowing with a fan of breath, which persons accustomed to the business know how to command. The hollow cylinder is then opened by holding it to the fire, which, by expanding the air confined within it, (the hole of the iron rod being stopped,) bursts it at the weakest part, and when still soft, it is ripped up through its whole length by iron shears, opened out into a flat plate, and finished by annealing as usual.

The large crown glass of Messrs. Hammond and Smith is superior in quality as well as in size to that of any other manufacture. The usual diameter of the tables in other manufactures may be taken at 47 or 48 inches, with an occasional variation in a table of one or two inches: and the largest square which can be cut from these measures about 24 inches by 20, and in some circumstances one inch wider or longer. Whereas the glass of Messrs. Hammond and Smith is 60 inches in diameter, and will admit of being cut into squares of about 33 inches by 23 inches; and a little more or less. This glass is almost free from those specks, wreaths, &c. which discolour other glass, and distort the objects seen through it. It now supplies the place of German sheet glass for prints, large sashes, and exportation to those foreign markets where that glass was formerly in use.

Glass, *French*, as also called *Normandy glass*, and formerly *Lorraine glass*, because it was made in those provinces: though it has since been made wholly in the nine glass works; five of which were in the forest of Lyons, four in the country of Eu; the last at Beaumont, near Rouen. It is of a thinner kind than our crown glass; and, when laid on a piece of white paper, appears of a dirtyish-green colour. There are but twenty-five tables of this to the case.

Glass, *German*, is of two kinds, the *white* and the *green*: the first is of a whitish colour, but is subject to those small curved streaks, observed in our Newcastle glass, though free from the spots and blemishes thereof. The green, besides its colour, is liable to the same streaks as the white; but both of them are straighter, and less warped, than our Newcastle glass

Glass, *Dutch*, is not much unlike our Newcastle glass, either in colour or price. It is frequently much warped, like that, and the tables are but small.

Glass, *Newcastle*, is that most used in England. It is of an ash-colour, and much subject to specks, streaks, and other blemishes; and, besides, is frequently warped. Leybourn says, there are forty-five tables to the case, each containing five superficial feet: some say there are but thirty-five tables, and six feet in each table.

Glass, *Phial*, is a kind of glass betwixt the flint glass and the common bottle, or green glass. The best kind may be prepared with a hundred and twenty pounds of white sand, fifty pounds of unpurified pearl-ashes, ten pounds of common salt, five pounds of arsenic, and five ounces of manganese. The composition for green or common phial glass, consists of a hundred and twenty pounds of the cheapest white sand, eighty pounds of wood ashes, well burnt and sifted, twenty pounds of pearl-ashes, fifteen pounds of common salt, and one pound of arsenic.

Glass, *common green bottle*, is made almost entirely of sand, lime, and sometimes clay, alkaline ashes of any kind, as cheapness or convenience direct, and more especially of kelp in this country, of barilla, varec, and the other varieties of soda in France, and of wood ashes in many parts of Germany, and the like. To these ingredients is sometimes added the earth remaining from saline ashes, after the alkali and salts have been extracted by lixiviation, and in England flags from the iron furnaces. Bottle-glass is a very hard well-vitrified glass, which resists the corrosive action of all liquids much better than flint glass. It is used, not only for wine-bottles, but for very large retorts, subliming vessels, and other articles of the chemical apparatus; and it has for this purpose the advantage of bearing as much as a pretty full red heat without melting or sinking down into a shapeless lump, as the lead-glasses would do. The following composition is given by Loysel as a good and cheap material for bottle-glass; *viz.* 100 parts of common sand, 30 of varec (a kind of coarse kelp made on the western coasts of France), 160 of the lixiviated earth of ashes, 30 of fresh wood-ash, or any other kind of ash, 80 of brick-clay, and any quantity, generally about 100, of broken glass. This composition yields no glass-gall. This kind of glass is formed of sand of any kind, fluxed by the ashes of burnt wood, or of any parts of vegetables; to which may be added the scoriæ or clinkers of forges. When the softest sand is used, two hundred pounds of wood-ashes will suffice for a hundred pounds of sand, which are to be ground and mixed together. The composition with the clinkers consists of a hundred and seventy pounds of wood-ashes, a hundred pounds of sand, and fifty pounds of clinkers, or scoriæ, which are to be ground and mixed together. If the clinkers cannot be ground, they must be broke into small pieces, and mixed with the other matter without any grinding.

A good bottle-glass, but nearly black and opaque, has been made in France of the decomposed pulverulent basaltic earth found in the vallies of all basaltic countries. In France it abounds in the Vivarais, in Languedoc, and Auvergne. The first glass of this kind appears to have been made in 1780 by a M. Ducros at the suggestion of Chaptal, who simply melted some of this basalt without addition in a glass-pot, and formed of it two very light, black, or rather deep yellow, shining, perfect bottles. In subsequent trials by another artist, a mixture of equal parts of basalt and sand was employed, as preferable to the basalt alone; but notwithstanding a considerable demand for bottles of this material, the manufacture was abandoned for want of uniformity in the ingredients, which made them often fail. The colour of this glass was of a green-olive.

The green colour, transmitted by bottle-glass, when in its perfect state, is owing to the iron contained both in the vegetable ashes and in the sea-sand, which enter into its composition. This glass affords an instance of a semi-pellucid substance, which exhibits a blue colour by incident light, and a yellow or orange colour by that which is transmitted. See Delaval on the cause of the permanent colour of opaque bodies.

Glass, *Plate*, is the most perfect and beautiful glass, of which all the kinds of mirrors and looking-glasses are composed. The materials of which this kind of glass is made are much the same as those of other works of glass, *viz.* an alkali salt, and sand.

To prepare the salt, they clean it well of all foreign matters; pound or grind it with a kind of mill, and finally sift it pretty fine.

Pearl-ashes, properly purified, will furnish the alkali salt requisite for this purpose; but it will be necessary to add borax, or common salt, in order to facilitate the fusion, and prevent the glass from stiffening in that degree of heat, in

which it is to be wrought into plates. For purifying the pearl-ashes, dissolve them in four times their weight of boiling water, in a pot of cast iron, always kept clean from rust. Let the solution be removed into a clean tub, and remain there twenty-four hours, or longer. Having decanted the clear part of the fluid from the dregs or sediment, put it again in the iron pot, and evaporate the water till the salts are left perfectly dry. Preserve them in stone jars, well secured from air and moisture.

Pearl-ashes may also be purified in the highest degree, so as to be proper for the manufacture of the most transparent glass, by pulverizing three pounds of the best pearl-ashes, with six ounces of salt-petre, in a glass or marble mortar, till they are well mixed; and then putting part of the mixture into a large crucible, and exposing it in a furnace to a strong heat. When this is red-hot, throw in the rest gradually; and when the whole is red-hot, pour it out on a moistened stone or marble, and put it into an earthen or clean iron pot, with ten pints of water; heat it over the fire till the salts be entirely melted; let it then stand to cool, and filter it through paper in a pewter cullender. When it is filtered, put the fluid again into the pot, and evaporate the salt to dryness, which will then be as white as snow; the nitre having burnt all the phlogistic matter that remained in the pearl-ashes, after their former calcination.

As to the sand, it is to be sifted and washed, till such time as the water come off very clear; and when it is well dried again, they mix it with the salt, passing the mixture through another sieve. This done, they lay them in the annealing furnace for about two hours; in which time the matter becomes very light and white: in this state they are called *frit*, or *fritta*; and are to be laid up in a dry clean place, to give them time to incorporate. They lie here for at least a year.

When they would employ this frit, they lay it for some hours in the furnace, adding to some the fragments or shards of old and ill made glasses; taking care first to calcine the shards by heating them red-hot in the furnace, and thus casting them into cold water. To the mixture must likewise be added manganese, to promote the fusion and purification.

The best composition for looking-glass plates is said to consist of sixty pounds of white sand cleansed, twenty-five pounds of purified pearl-ashes, fifteen pounds of salt-petre, and seven pounds of borax. If a yellow tinge should affect the glass, a small proportion of manganese, mixed with an equal quantity of arsenic, should be added. An ounce of the manganese may be first tried; and if this proves insufficient, the quantity should be increased.

A cheaper composition for looking-glass plate consists of sixty pounds of the white sand, twenty pounds of pearl-ashes, ten pounds of common salt, seven pounds of nitre, two pounds of arsenic, and one pound of borax.

The materials of the finest plate glass, such as that of French manufacture, are white sand, soda, and lime, to which are added manganese and zaffre, or any other oxyd of cobalt for particular colouring purposes. The sand is of the finest and whitest kind, which should be previously passed through a wire sieve, moderately close, into water, in which it should be well stirred about and washed. The sharpest grained sand is preferred, and it is found that grains of moderate size melt with the alkali sooner, than the very fine dust or the larger fragments. The alkali is always soda, which is preferable to potash, as glasses made with soda are found to be softer and to flow thinner when hot, and yet to be equally durable when cold. Besides, the neutral salts with the basis of soda which constitute the glass-gall in this instance, such as the muriat and sulphat of soda, appear to be dissipated more readily by the fire than the corresponding salts of potash. The soda that is used is considerably pure, or such as is separated from the rough ashes of barilla, and other soda plants by lixiviation. Lime adds to the fusibility of the other materials, supplying the use of litharge in the flint-glass; but excess of it would impair the colour and solidity of the glass. About 1-15th of the whole is as much as can properly be used; but some reduce the quantity to 1-24th. The decolouring substances are azure, or cobalt blue, and manganese. Besides these, there is always a great quantity of the fragments of glass, collected from the waste of the manufacture, which are made friable by quenching in water when hot, and used in this state together with the fresh materials. As to the quantities and proportions of the ingredients, much latitude is allowed. The following are said to produce a very fine glass; *viz.* 300lbs. of sand; 200lbs. of soda; 30lbs. of lime; 32 ounces of manganese; three ounces of azure; and 300lbs. of fragments of glass. In the manufactory at St. Gobin secrecy is observed with regard to the materials; but it is affirmed, and with much probability, that borax is used in small quantity.

Of the materials now enumerated the sand, soda, lime, and manganese are first mixed together with more care than for ordinary glass, and they are fritted in small furnaces built for this purpose, the heat being gradually raised to a full red-white, and then kept with frequent stirring till the materials undergo no farther change, nor yield any kind of vapour. The azure and glass fragments being already in a state of perfect vitrification are not added till just at the end of the process, which lasts about six hours. When the materials are thus prepared, they are fit for plate-glass, to be formed either by blowing or casting. The largest glasses at St. Gobin are run; the middle-sized and small ones are blown.

Blowing looking-glass plates. The work-houses, furnaces, &c. used in the making of this kind of plate-glass, are the same, except that they are smaller, and that the carquaisses are disposed in a large covered gallery, over-against the furnace, as those in the following article, to which the reader is referred.

After the materials are vitrified by the heat of the fire, and the glass is sufficiently refined, the workman dips in his blowing iron, six feet long, and two inches in diameter, sharpened at the end, which is put in the mouth, and widened at the other, that the matter may adhere to it. By this means he takes up a small ball of matter, which sticks to the end of the tube by constantly turning it. He then blows into the tube, that the air may swell the annexed ball: and carrying it over a bucket of water, which is placed on a support at the height of about four feet, he sprinkles the end of the tube to which the matter adheres, with water, still turning it, that by this cooling, the matter may coalesce with the tube, and be fit for sustaining a greater weight. He dips the tube again into the same pot, and proceeds as before; and, dipping it in the pot a third time, he takes it out, loaded with matter, in the shape of a pear, about ten inches in diameter, and a foot long, and cools it at the bucket; at the same time blowing into the tube, and, with the assistance of a labourer, giving it a balancing motion, he causes the matter to lengthen; which, by repeating this operation several times, assumes the form of a cylinder, terminating like a ball at the bottom, and in a point at the top. The assistant is then placed on a stool three feet and a half high; and on this stool there are two

upright pieces of timber, with a crofs beam of the fame, for fupporting the glafs and tube, which are kept in an oblique pofition by the affiftant, that the mafter workman may with a puncheon fet in a wooden handle, and with a mallet make a hole in the mafs: this hole is drilled at the centre of the ball that terminates the cylinder, and is about an inch in diameter. When the glafs is pierced, the defects of it are perceived; if it is tolerably perfect, the workman lays the tube horizontally on a little iron treffel, placed on the fupport of the aperture of the furnace. Having expofed it to the heat for about half a quarter of an hour, he takes it away, and with a pair of long and broad fhears, extremely fharp at the end, widens the glafs, by infinuating the fhears into the hole made with the puncheon, whilft the affiftant, mounted on the ftool, turns it round, till, at laft, the opening is fo large as to make a perfect cylinder at bottom. When this is done, the workman lays his glafs upon the treffel, at the mouth of the furnace, to heat it: he then gives it to his affiftant on the ftool, and with large fhears cuts the mafs of matter up to half its height. There is at the mouth of the furnace an iron tool, called *pontil*, which is now heating, that it may unite and coalefce with the glafs juft cut, and perform the office which the tube did before it was feparated from the glafs. This pontil is a piece of iron, fix feet long, and in the form of a cane or tube, having at the end of it a fmall iron bar, a foot long, laid equally upon the long one, and making with it a T. This little bar is full of the matter of the glafs, about four inches thick. This red-hot pontil is prefented to the diameter of the glafs, which coalefces immediately with the matter round the pontil, fo as to fupport the glafs for the following operation. When this is done, they feparate the tube from the glafs, by ftriking a few blows with a chiffel upon the end of the tube, which has been cooled; fo that the glafs breaks directly, and makes this feparation, the tube being difcharged of the glafs now adhering to the pontil. They next prefent to the furnace the pontil of the glafs, laying it on the treffel to heat, and redden the end of that glafs, that the workman may open it with his fhears, as he has already opened one end of it, to complete the cylinder; the affiftant holding it on his ftool as before. For the laft time, they put the pontil on the treffel, that the glafs may become red-hot, and the workman cuts it quite open with his fhears, right over-againft the fore-mentioned cut; this he does as before, taking care that both cuts are in the fame line. In the mean time, the man who looks after the carquaiffes, comes to receive the glafs upon an iron fhovel, two feet and a half long without the handle, and two feet wide, with a fmall border of an inch and a half to the right and left, and towards the handle of the fhovel. Upon this the glafs is laid, flattening it a little with a fmall ftick a foot and a half long, fo that the cut of the glafs is turned upwards. They feparate the glafs from the pontil, by ftriking a few gentle blows between the two with a chiffel. The glafs is then removed to the mouth of the hot carquaiffe, where it becomes red-hot gradually; the workman, with an iron tool, fix feet long, and widened at the end in form of a club at cards, four inches long, and two inches wide on each fide, very flat, and not half an inch thick, gradually lifts up the cut part of the glafs, to unfold it out of its form of a flattened cylinder, and render it fmooth, by turning it down upon the hearth of the carquaiffe. The tool, already defcribed, being infinuated within the cylinder, performs this operation, by being pufhed hard againft all the parts of the glafs. When the glafs is thus made quite fmooth, it is pufhed to the bottom of the carquaiffe, or annealing furnace, with a fmall iron raker, and ranged there with a little iron hook. When the carquaiffe is full, it is ftopped and cemented as in the cafe of run glaffes, and the glafs remains there for a fortnight to be annealed; after which time, they are taken out to be polifhed. A workman can make but one glafs in an hour, and he works and refts for fix hours alternately.

It may be obferved, that looking-glaffes, thus blown, fhould never be above forty-five, or at moft fifty inches long, and of a breadth proportionable. Thofe exceeding thefe dimenfions, as we frequently find among the Venice glaffes, cannot have the thicknefs fufficient to bear the grinding; and, befides, are fubject to warp, which prevents them from regularly reflecting objects. Whereas plates as large as nine feet in length and proportionally wide, have been manufactured by cafting.

Cafting or running large Looking-glafs plates. This art, as we have obferved in the *Hiftory of* GLASS, is of French invention. It is owing to the Sieur Abraham Thevart, who firft propofed it to the court of France, in 1688.

It is performed much like the cafting of fheet-lead among the plumbers; and by means hereof we are not only enabled to make glaffes of more than double the dimenfions of any made by the Venetian way of blowing; but alfo to caft all kinds of borders, mouldings, &c.

The furnaces for melting the materials of this manufacture are of large fize, being about 18 feet long and 15 wide; and thofe for annealing the glaffes, when formed, are much more fo Round a melting-furnace, there are at leaft twenty-four annealing furnaces or ovens; each from twenty to twenty-five feet long; they are called carquaiffes: each carquaiffe has two tiffarts, or apertures, to put in wood, and two chimnies. Add, that befide the annealing furnaces, &c. there are others for making of frit, and calcining old pieces of glafs.

All thefe furnaces are covered over with a large fhed; under which are likewife forges, and work-houfes for fmiths, carpenters, &c. continually employed in repairing and keeping up the machines, furnaces, &c. as alfo lodges, and apartments for thefe, and the other workmen, employed about the glafs, and keeping up a perpetual fire in the great furnace; fo that the glafs-houfe, as that in the caftle of St. Gobin, in the foreft of Fere, in the Soiffonois, appears more like a little city, than a manufactory.

The infide of furnaces is formed of a fort of baked earth, or refractory clay, proper to fuftain the action of fire; and the fame earth ferves alfo for melting-pots, cifterns, &c. The furnaces feldom laft above three years; after which they are to be rebuilt, from bottom to top; and to keep them good, even for that time, the infide muft be refitted every fix months, at which time the fire is extinguifhed. The fmelting-pots are as big as wine hogfheads, about three feet in height, and in diameter; and contain above two thoufand weight of metal. They are in the form of an inverted and truncated cone. The cifterns, or pans, called "cuvettes," are much fmaller, being about thirty-fix inches long, eighteen inches wide, and as many deep; and ferve for the conveyance of liquid glafs, which is drawn out of the pots to the cafting tables. They do not contain much more than a fixth, or when large plates are caft, a third of the pots.

When the furnace is in condition to receive the pots and cifterns, they heat it red-hot, which requires fifty cords, or a hundred cart-loads of wood. That kind of wood which emits the largeft and brighteft flame, without much refinous fmoke, is preferred. This done, they fill the pots with the materials, or foda and fand, which is done at feveral times, to facilitate the fufion. When the matter is fufficiently vitrified, refined, and fettled, which ufually happens in

thirty-six hours, they fill the cisterns, which are in the same furnace, and which are left there about six hours longer, till such time as they appear all white through the excessive heat.

To get the cisterns with the metal out of the furnace, they make use of a large iron chain which opens and shuts with hooks and eyes. From the middle of this, on each side, arise two massive iron pins, by which, with the assistance of pullies, the cisterns are raised upon a kind of carriage of a proper height; and thus conducted to the table where the glass is to be run. The cistern is then raised above the tables with an engine, in form of a crane, by means of two iron bars, so contrived as to throw the cistern into an inclined position, which discharges a torrent of matter, all on fire, with which the table prepared for this purpose is presently covered.

The table on which the glass is to be run, is of smooth thick copper-plate, about ten feet long, and six feet broad. It is supported on a wooden frame, with truckles, for the convenience of removing from one carquaisse, or annealing furnace, to another, in proportion as they are filled.

Or, when each pot has a casting table, it is strongly supported by masonry, and contiguous to each table on the same level are the annealing ovens, upon which, being flat, the glass, when cast and sufficiently cooled, may be slid from off the copper-table without much difficulty. The tops of the flat ovens and the tables are on a level with the corresponding opening of the furnace, whence the cuvettes or cisterns are withdrawn. When the glass is melted and fined in the manner already stated under the article *Flint* GLASS, the cuvette or cistern, previously made hot in the furnace, is filled out of the pot with a copper ladle, about ten inches in diameter, fixed to an iron handle seven feet long, properly supported on an iron stay by two workmen; and after remaining in the furnace for some hours, till the samples taken out for trial appear to be quite clear and limpid, the door of the furnace is opened, and the cuvette is pulled out and removed to the side of the copper table. It is then scummed with an instrument consisting of a copper blade set in iron, and hoisted for the discharge of its contents on the table, in the manner already mentioned.

To form the thickness of a glass, and to make the surface smooth and even, there are two iron rulers or rims, placed round the edge of the table; and on these rest the two extremes of a kind of roller, or hollow heavy cylinder of copper, turned after being cast, and about 500 pounds in weight, which serves to drive the liquid matter before it to the end of the table, or mould. The iron rulers being moveable, and capable of being set closer, or farther apart, at pleasure, determine the width of the glasses, and retain the matter, that it does not run off at the edges. The waste glass, if any, falls into a vessel of water, and is reserved for the next melting.

As soon as the matter is arrived at the end of the table, and the glass is come to a consistence, examined by the directors of the manufacture, and approved, they shove it off into the annealing furnace, with an iron raker, as wide as the table, that has a handle two fathoms long; being assisted by workmen on the other side of the carquaisse, who, with iron hooks, pull the glass to them, and range it in the carquaisse, which holds six large glasses.

What is most surprising throughout the whole of this operation, is the quickness and address wherewith such massy cisterns, filled with a flaming matter, are taken out of the furnace, conveyed to the table, and poured on it, the glass spread, &c. The whole is inconceivable to such as have not been eye-witnesses of that surprising manufacture.

As fast as the cisterns are emptied, they carry them back to the furnace and take fresh ones, which they empty as before. This they continue to do, so long as there are any full cisterns; laying as many plates in each carquaisse as it will hold, and stopping them up with doors of baked earth, or clay, and every chink with cement, as soon as they are full, to let them anneal, and cool again, which requires about fourteen days.

The first running being dispatched, they prepare another, by filling the cisterns anew, from the matter in the pots; and after the second, a third, and even a fourth time, till the melting-pots are quite empty.

The cisterns at each running should remain at least six hours in the furnace to whiten; and when the first annealing furnace is full, the casting table is to be carried to another. It need not here be observed, that the carquaisses, or annealing furnaces, must first have been heated to the degree proper for them. It may be observed, that the oven full, or the quantity of matter commonly prepared, supplies the running of eighteen glasses, which is performed in eighteen hours, being an hour for each glass. The workmen work six hours, and are then relieved by others.

When the pots are emptied, they take them out, as well as the cisterns, to scrape off what glass remains, which otherwise would grow green by continuance of fire, and spoil the glasses. They are not filled again in less than thirty-six hours, so that they put the matter into the furnace, and begin to run it every fifty-four hours.

The manner of heating the large furnaces is singular enough; the two tisors, or persons employed for that purpose, in their shirts, run round the furnace without making the least stop, with a speed scarce inferior to that of the lightest courier: as they go along, they take two billets, or pieces of wood, which are cut for the purpose; these they throw into the first tissart; and continuing their course do the same for the second. This they hold without interruption for six hours successively; after which they are relieved by others, &c. It is surprising that two such small pieces of wood, and which are consumed in an instant, should keep the furnace to the proper degree of heat; which is such, that a large bar of iron, laid at one of the mouths of the furnace, becomes red-hot in less than half a minute.

It is computed, that a furnace, before it be fit to run glass, costs above three thousand five hundred pounds; that at least six months are required for the building it anew, and three months for the refitting it; and that when a pot of matter bursts in the furnace, the loss of matter and time amounts to above two hundred and fifty pounds.

The glass, when taken out of the melting-furnace, needs nothing farther but to be ground, polished, and foliated. But before these operations are performed, they cut and square the edges of the plates; which is performed with a rough diamond, passed along the surface of the glass, upon a square ruler, like that of the glaziers, and made to cut into the substance of the glass to a certain depth. This cut is then opened by gently knocking with a small hammer on the under side of the glass, just under it; by which means the piece comes off, and the roughnesses of the edges are removed by pincers. The plates are then laid by for *grinding*,

polishing, and *silvering*; which see respectively. See also LOOKING-GLASS.

GLASS, *Annealing* or *Nealing of*. The operation of annealing of glass is performed in a peculiar furnace called the *leer*, which consists of two parts, the *tower* and *leer*. The vessels, as soon as made, are placed by the workmen on the floor of the former to anneal: which done, they are drawn slowly in a sort of pan, called *fraches*, by an operator called the *sarole-man*, all along the latter, the space of five or six yards, to give them time to cool gradually; so that when they reach the mouth of it, they are found quite cold. Merret, Not. to Neri, p. 243, seq.

This annealing is generally performed in a hot chamber, built for the purpose, at the top of the glass-house, above the crucibles, and a little below the chimney. Without this precaution, the glass would be liable to fly and break, by the least change of heat and cold, by the smallest scratch, and sometimes without any apparent external cause. The hard glasses, and those especially that are made with alkali and earths, require much more annealing than the softer and more fusible glasses, containing in their composition much litharge.

The particles of glass by annealing are supposed to lose part of their springiness, and their brittleness at the same time. A gradual heating or cooling of glass, according to Dr. Hook, anneals or reduces its parts to a texture more loose, and easy to be broke; but withal more flexible than before. And hence in some measure the phenomena of glass-drops.

Some of the phenomena depending on the fragility of unannealed glass deserve the attention of the curious. Those of the lachrymæ, or glass-drops, were among the first taken notice of; and it has also been observed, that hollow bells made of unannealed glass, with a small hole in them, will fly to pieces by the heat of the hand only, if the hole by which the internal and external air communicate be stopped with a finger. Phil. Transf. N° 477. § 3. See RUPERT's *Drops*.

But lately some vessels made of such unannealed glass have been discovered, which have the remarkable property of resisting very hard strokes given from without, though they shiver to pieces by the shocks received from the fall of very light and minute bodies dropped into their cavities. Of this kind is the "Bologna phial." These glasses may be made of any shape; all that needs be observed in making them, is to take care that their bottoms may be thicker than their sides. The thicker the bottom is, the easier do the glasses break. One whose bottom is three fingers breadth in thickness, flies with as much ease at least as the thinnest glass. Some of these vessels have been tried with strokes of a mallet sufficient to drive a nail into wood tolerably hard, and have resisted fracture. They also resist the shock of several heavy bodies let fall into their cavities, from the height of two or three feet. For instance, musket-balls, pieces of iron, or other metal; pyrites, jasper, wood, bone, &c. but this is not surprising, as other glasses of the same size do the same. But the wonder is, that taking a shiver of flint of the size of a small pea, and letting it fall into the glass only from the height of three inches, in about two seconds the glass flies, and sometimes in the very moment of the shock; nay, a bit of flint, no larger than a grain, dropt into several glasses successively, though it did not immediately break them, yet they all flew, being set by, in less than three quarters of an hour. Phil. Transf. ibid. p. 509.

Some other bodies produce a like effect with flint: for instance, sapphire, porcelain, diamonds, hard tempered steel, as also marbles, such as boys play with; to which add pearls from the animal kingdom.

The experiment succeeded also when the glasses were held in the hand, rested on a pillow, put in water, or filled with water. It is also remarkable, that the glasses broke upon their bottoms being slightly rubbed with the finger, though some of them did not fly till half an hour after the rubbing.

If the glasses be every where extremely thin, they do not break in these circumstances.

Some have pretended to account for these phenomena, by saying, that the bodies dropped into these vessels cause a concussion, that is stronger than the cohesion of the parts of the glass, and that consequently a rupture of the same must ensue. But why does not a ball of gold, silver, iron, copper, or several other bodies, even a thousand times heavier than a shiver of flint, equally cause this concussion, and break the glasses?

Mr. Euler has endeavoured to account for these appearances from his Principles of Percussion. He thinks this experiment entirely overthrows the opinion of those who measure the force of percussion by the *vis viva*; and he thinks the principles he has established give a clear solution of this phenomenon. According to these principles, the extreme hardness of the flint, and also its angular figure, which makes the space of contact with the glass vessel extremely small, ought to cause an impression on the glass vastly greater than lead or any other metal; and this may account for the flint's breaking the vessel, though the bullet, even falling from a considerable height, does no damage. Mem. Acad. Berlin, 1745, p. 47.

Hollow cups, made of the green bottle-glass, some of them three inches thick at bottom, were instantly broken, by a shiver of flint weighing about two grains, though they had resisted the shock of a musket ball from the height of three feet. Phil. Transf ibid. p. 515.

"The precise mechanical cause of this disposition to crack in unannealed glass, is very difficult to explain," says Aikin (Dict.), "but generally speaking, it is supposed to be the forcible contraction of the outer part by sudden cooling, whilst the inner portion is still soft and half-fluid, so that the whole fixes with a permanent strain or inequality of pressure of one part upon the other; and as glass is extremely elastic, though brittle, any force which tears asunder a portion, however small, of the tense part, communicates a strong and sudden impulse over the whole mass." "This most singular phenomenon," (of the Rupert's drop) says the same ingenious chemist, in consequence of his own experiments, "is obviously owing to some permanent and very strong inequality of pressure, for when they are heated so red, as to be soft and merely let to cool of themselves, this property of bursting is entirely lost, and, at the same time, the specific gravity of the drop is increased. The peculiar brittleness of the Bologna phial is also removed by again heating and cooling slowly." The common window-glass, when badly annealed, is cut by the diamond with difficulty, and the cut often flies in a direction different from what was intended, or the glass entirely breaks.

Among other more common defects of glass, we may mention its liability to be acted upon by corrosive liquors, as is the case when too much saline flux has been used. As impenetrable as glass is to the common menstruums, we find it eaten by the air in length of time, when exposed in old windows; but the effects of its being kept in a subterraneous place are much more strange. Borrichius tells us, that at

the time when he was at Rome, there was dug up a whole houſe from under the kitchen garden of a citizen. The houſe had been buried there ten ages, and there were found in it ſeveral glaſs urns, or lacrymatories. The glaſs of theſe had no holes made in it, as our old glaſs in chamber-windows has, but ſtill retained its ſmooth ſurface and tranſparence; but it was ſplit into a vaſt number of thin laminæ, which were as pellucid and fine as Muſcovy glaſs; and in ſome places were tinged with all the beautiful colours that art could have given. We are not acquainted perfectly with the ancient way of working their glaſs; but it is not probable there could be any thing particular in the formation of the veſſel, to determine it to ſplit thus into flakes; but that glaſs of the ſame kind, in any form, would have done the ſame. Borrich de Ortu Chemiæ.

There are other viſible imperfections in glaſs, materially injuring its ſoundneſs and beauty, and enumerated by Aikin (Dict. art. *Glaſs*) under the denominations of *ſtriæ*, *threads*, *tears*, and *knots*. The former are undulating waves in the glaſs, ariſing from the imperfect mixture of the materials, and their different ſpecific gravities. Accordingly, we may obſerve, that the moſt tranſparent glaſs is ſubject to bubbles and veins, the methods of preventing which are yet little known; and this is an inconvenience by which Mr. Dollond's excellent diſcovery is affected; for the flint-glaſs which he uſes is peculiarly ſubject to ſmall veins, that diſturb the rays in their paſſage, and render the viſion confuſed. This effect is owing to the denſity of theſe veins being greater than that of the reſt of the glaſs, as appears from their image received on white paper, when the glaſs is held between the paper and a candle, or other luminous object: for this image of a thus received, is a line brighter than the reſt of th image of the glaſs, and this bright line is defined by a dark edge on each ſide. But the bright line evidently ſhews a convergency of rays, which can only be effected by the veins being denſer than the medium in which they are placed. The reaſon why flint glaſs is more ſubject to veins than other glaſs is, ſays the tranſlator of Macquer's Chemical Dictionary, becauſe it is compoſed of materials of more different denſities.

Mr. Macquer, with a view of improving the manufacture of this glaſs, propoſes to facilitate the union of the calx of lead and ſand, of which it is compoſed, by depriving the calx of lead, as much as poſſible, of its phlogiſton, which may be done by combining the vitriolic acid with minium, or red-lead, and expoſing this compoſition to the operation of fire, to diſengage it from the acid; and alſo by giving theſe two ſubſtances the greateſt poſſible degrees of fluidity and mobility, which may be done by mixing with the compoſition of them a conſiderable quantity of ſolvents. Hiſt. Acad. Scienc. for 1773.

Threads in glaſs, are thoſe ſtreaky filaments which ariſe from the vitrification of the clay; being generally green, and rendering the glaſs more liable to crack at theſe parts. But one of the worſt defects (ſays Aikin, *ubi ſupra*), is "*tears*, or drops of vitrified clay falling down from the furnace into the pots, and entangled with the glaſs. Articles made of glaſs with this defect, are always very brittle, and generally break of themſelves by ſlight changes of heat and cold." Small bubbles appear in glaſs not ſufficiently refined by a continuance of the melting heat; and theſe may be owing to a deficiency of flux, ſo that the glaſs is leſs fuſible, and the bubbles cannot eaſily be diſengaged. "Hence," ſays the author now cited, "the ſoft fuſible glaſſes with much lead are much leſs liable to this fault than the hard, green bottle-glaſs, which is made only of alkali and earth." The *knots* in glaſs "ariſe either from a portion of ſand that has eſcaped vitrification, and remains entangled in the glaſs, or from a remaining quantity of glaſs-gall; or from bits of the crucible which may be accidentally knocked off by the iron inſtruments uſed in the working."

GLASS *of Antimony*. See *Oxyds of* ANTIMONY and VITRUM *Antimonii ceratum*.

GLASS, *Axungia of*. See AXUNGIA, SANDIVER, and GLASS, *ſupra*.

GLASS *of Borax*. See BORAX.

GLASS, *Colouring of, to imitate gems*. See GEMS.

GLASS, *Gold-coloured* This kind of glaſs may be made by taking ten pounds of either of the compoſitions for hard glaſs, omitting the ſalt-petre; and for every pound adding an ounce of calcined borax; or, if this quantity doth not render the glaſs ſufficiently fuſible, two ounces; ten ounces of red tartar, of the deepeſt colour, two ounces of mangaeſe, and two drams of charcoal of ſallow, or any other ſoft kind. Precipitate of ſilver baked on glaſs will ſtain it yellow, and likewiſe give a yellow colour on being mixed with and melted with forty or fifty times their weight of vitreous compoſitions; the precipitate from aqua-fortis by fixed alkali ſeems to anſwer beſt. Yellow glaſſes may alſo be obtained with certain preparations of iron, particularly with Pruſſian blue. But Dr Lewis obſerves, that the colour does not conſtantly ſucceed, nor approach to the high yellow of gold, with ſilver or with iron. The neareſt imitations of gold which he has been able to produce, have been effected with antimony and lead. Equal parts of the glaſs of antimony, of flint calcined and powdered, and of minium, formed a glaſs of a high yellow; and with two parts of glaſs of antimony, two of minium, and three of powdered flint, the colour approached ſtill more to that of gold. The laſt compoſition exhibited a multitude of ſmall ſparkles interſperſed through its whole ſubſtance, which gave it a beautiful appearance in the maſs, but were really imperfections, owing to air-bubbles.

Neri directs, for a gold-yellow colour, one part of red tartar, and the ſame quantity of manganeſe, to be mixed with a hundred parts of frit. But Kunckel obſerves, that theſe portions are faulty; that one part, or one and a quarter of manganeſe, is ſufficient for a hundred of frit; but that ſix parts of tartar are hardly enough, unleſs the tartar is of a dark red colour, almoſt blackiſh; and that he found it expedient to add to the tartar about a fourth of its weight of powdered charcoal. He adds, that the glaſs ſwells up very much in melting, and that it muſt be left unſtirred and worked as it ſtands in fuſion. Mr. Samuel More, in repeating and varying this proceſs, in order to render the colour more perfect, found that the manganeſe is entirely eſſential to the gold colour, and that the tartar is no otherwiſe of uſe, than in virtue of the coaly matter, to which it is in part reduced by the fire; the phlogiſton or inflammable part of the coal appearing in ſeveral experiments to be the direct tinging ſubſtance. Mr. Pott alſo, in his Neue Wichtige Phyſicaliſchch-Chymiſche Materien, &c. printed in 1762, obſerves, that common coals give a yellow colour to glaſs; that different coaly matters differ in their tinging power; that caput mortuum of ſoot and lamp-black anſwer better than common charcoal; and that the ſparkling coal which remains in the retort after the rectification of the thick empyreumatic animal oils, is one of the moſt active of theſe preparations. This preparation, he ſays, powdered, and then burnt again a little in a cloſe veſſel, is excellent for tinging glaſs, and gives yellow, brown, reddiſh, or blackiſh colour, according to its quantity: but the frit muſt not be very

hard of fusion; for, in this case, the strong fire will destroy the colouring substance before the glass melts, and he has found the following compositions to be nearly the best; *viz.* sand two parts, alkali three parts; or sand two, alkali three, calcined borax one; or sand two, alkali two, calcined borax one: and though salt-petre is hardly used at all, or very sparingly, for yellow glasses, as it too much volatilizes the colouring substance; yet here for the most part a certain proportion of it, easily determined by trial, is very necessary; for without it, the concentrated colouring matter is apt to make the glass too dark, and even of an opaque pitchy blackness. It does not certainly appear that there is any material diversity in the effects of different coals; the difference being probably owing to the different quantities of the inflammable matter which they contain; so that a little more shall be required of one kind than of another, for producing the same degree of colour in the glass. Nor does the softness or fusibility of the frit appear to be in any respect necessary.

Gold-coloured spangles may be diffused through the substance of glass, by mixing the yellow talcs with powdered glass, and bringing the mixture into fusion. See Lewis's Com. Phil. Techn. p. 223. 626, &c.

Glass *for counterfeiting lapis lazuli.* See *Lapis* Lazuli.

Glass *resembling opal.* See Opal and Gems.

Glass, *Ruby.* The way to give the true fine red of the ruby, with a fair transparence, to glass, is as follows. Calcine in earthen vessels gold dissolved in aqua regia, the menstruum being evaporated by distillation, more aqua regia added, and the abstraction repeated five or six times, till it becomes a red powder. This operation will require many days in a hot furnace; when the powder is of a proper colour, take it out; and when it is to be used, melt the finest crystal glass, and purify it, by often casting it into water; and then add, by small quantities, enough of this red powder to give it the true colour of a ruby, with an elegant and perfect transparence. Neri. See Gems.

The process of tinging glass and enamels by preparations of gold, were first attempted about the beginning of the 17th century. Libavius, in one of his tracts, entitled Alchymia, printed in 1606, conjectures that the colour of the ruby proceeds from gold, and that gold dissolved, and brought to redness, might be made to communicate a like colour to factitious gems and glass. On this principal Neri, in his "Art of Glass," dated 1611, gives the process above recited. Glauber, in 1648, published a method of producing a red colour by gold, in a matter which is of the vitreous kind, though not perfect glass. For this purpose he ground powdered flint or sand with four times its weight of fixed alkaline salt; this mixture melts in a moderately strong fire, and when cold looks like glass, but exposed to the air runs into a liquid state. On adding this liquor to solution of gold in aqua regia, the gold and flint precipitate together in form of a yellow powder, which by calcination becomes purple; by mixing this powder with three or four times its weight of the alkaline solution of flint, drying the mixture, and melting it in a strong fire for an hour, a mass is obtained, of a transparent ruby colour, and of a vitreous appearance, which nevertheless is soluble in water, or by the moisture of the air, on account of the redundance of the salt. The honourable Mr. Boyle, in a work published in 1680, mentions an experiment, in which a like colour was introduced into glass without fusion; for, having kept a mixture of gold and mercury in digestion for some months, the fire was at last immoderately increased, so that the glass burst with a violent explosion; and the lower part of the glass was found tinged throughout of a transparent red colour, hardly to be equalled by that of rubies. See Porosity of Bodies, in Shaw's Abridgment of Boyle's Works, vol. i. p. 459; and Appendix to the Sceptical Chemist.

About the same time Cassius is said to have discovered the precipitation of gold by tin, and that glass might be tinged of a ruby colour by melting it with this precipitate: though he does not appear, says Dr. Lewis, from his treatise De Auro, to have been the discoverer of either. He describes the preparation of the precipitate and its use, but gives no account of the manner of employing it; only that he says, one dram of gold, duly prepared, will tinge ten pounds of glass. See Gold *precipitate with tin.*

This process was soon after brought to perfection by Kunckel; who says, that one part of the precipitate is sufficient to give a ruby colour to 1280 parts of glass, and a sensible redness to upwards of 1900 parts; but that the success is by no means constant. Kunckel also mentions a purple-gold powder, resembling that of Neri, which he obtained by inspissating solution of gold to dryness, abstracting from it fresh aqua regia three or four times, till the matter appears like oil; then precipitating with strong alkaline ley, and washing the precipitate with water. By dissolving this powder in spirit of salt, and precipitating it again, it becomes, he says, extremely fair; and in this state he directs it to be mixed with a due proportion of Venice glass.

Orschal in his treatise entitled Sol sine Veste, gives the following process for producing a very fine ruby. He directs the purple precipitate, made by tin, to be ground with six times its quantity of Venice glass into a very fine powder, and this compound to be very carefully mingled with the frit or vitreous composition to be tinged. His frit consists of equal parts of borax, nitre, and fixed alkaline salt, and four times as much calcined flint as of each of the salts; but he gives no directions as to the proportion of the gold precipitate, or mode of fusion. Hellot describes a preparation, which mixed with Venice glass, was found to give a beautiful purple enamel. This preparation consists of equal parts of solution of gold, and of solution of zinc in aqua regia, mixed together with the addition of a volatile salt prepared from sal ammoniac, in quicklime, in sufficient quantity to precipitate the two metals. The precipitate is then gradually heated, till it acquires a violet colour. However, though a purple or red colour, approaching to that of ruby, may, by the methods above recited, be baked on glass or enamels, and introduced into the mass by fusion, the way of equally diffusing such a colour through a quantity of fluid glass is still, says Dr. Lewis, a secret. The following process for making the ruby glass was communicated to Dr. Lewis by an artist, who ascribed it to Kunckel. The gold is directed to be dissolved in a mixture of one part of spirit of salt, and three of aqua-fortis, and the tin in a mixture of one part of the former of these acids with two of the latter. The solution of gold being properly diluted with water (see Gold *precipitate,* &c.) the solution of tin is added, and the mixture left to stand till the purple matter has settled to the bottom. The colourless liquor is then poured off, and the purple sediment, while moist and not very thick, is thoroughly mixed with powdered flint or sand. This mixture is well ground with powdered nitre, tartar, borax, and arsenic, and the compound melted [illegible]

[illegible] Lewis's Com. Phil. Techn. p. 171. 621, &c.

Glass, *white-opaque,* and *semi-transparent,* may be made of ten pounds of either of the compositions for hard glass, and

one pound of well calcined horn, ivory, or bone; or an opaque whiteneſs may be given to glaſs, by adding one pound of very white arſenic to ten pounds of flint glaſs. Let them be well powdered and mixed, by grinding them together; and then fuſed with a moderate heat, till they are thoroughly incorporated. A glaſs of this kind is made in large quantities at a manufacture near London, and uſed not only for different kinds of veſſels, but as a white ground for enamel in dial-plates and ſnuff-boxes, which do not require finiſhing with much fire, becauſe it becomes very white and fuſible with a moderate heat.

Glass, *Yellow*. See *Golden-coloured* Glass.

Glass-*balls*, which are circular or otherwiſe ſhaped hollow veſſels of glaſs, may be coloured within, ſo as to imitate the ſemi-pellucid gems. The method of doing it is this: make a ſtrong ſolution of ichthyocolla, or iſinglaſs, in common water, by boiling; pour a quantity of this while warm into the hollow of a white glaſs veſſel; ſhake it thoroughly about, that all the ſides may be wetted, and then pour off the reſt of the moiſture. Immediately after this, throw in red lead, ſhake it and turn it about, throw it into many places with a tube, and the moiſture will make it ſtick and run in waves and pretty figures. Then throw in ſome of the painter's blue ſmalt, and make it run in waves in the ball as the red-lead; then do the ſame with verdigris, next with orpiment, then with red lake, all well ground; always caſting in the colours in different places, and turning the glaſs, that the moiſture within may run them into the waves. Then take fine plaſter of Paris, and put a quantity of it into the ball; ſhake it alſo nimbly about; this will every where ſtick firmly to the glaſs, and give it a ſtrong inner coat, keeping all the colours on very fairly and ſtrongly.

Theſe are ſet on frames of carved wood, and much eſteemed as ornaments in many places. Neri.

Glass-*drops*. See Rupert's *drops*.

Glass, *Foliating of*. See Foliating and Looking-glass.

Glass-*gall*, or *ſandiver*, is the ſcum of the glaſs pots, which ariſes during the vitrification of the frit. See Glass, *ſupra*.

Glass, *gilding of*. See Gilding *of enamel* and *glaſs*.

Glass, *grinding of*. See Grinding

Glass-*houſe Furnace*, is the place in which the ingredients or materials of glaſs are fuſed and vitrified. There are three kinds of furnaces uſed in the glaſs-works. The *firſt*, called the "calcar," ſerves for preparing or calcining the frit. It is made like an oven, 10 feet long, ſeven broad, and two deep. The fuel, which is ſea-coal, is put in a trench, on one ſide of the furnace; and the flame reverberates from the roof back upon the frit. The coals burn in an iron grate, and the aſhes fall thence into holes underneath.

The *ſecond* is the "working furnace," in which the ingredients are melted, and the glaſs is made. Its figure is round, reſembling a dome; three yards in diameter, and two high, ſupported on arches, beneath which is a large ſpace for a briſk and copious draught of cold air from without: round the inſide there are arranged eight or more pots, and on theſe piling-pots, every where cloſed except at one ſide opening, which communicates with a ſmall receſs formed by the alternate projections of the maſonry and flues of the oven or kiln, in which receſs the workmen ſtand. The furnace has two partitions; the lower, ſeparating the pots from the fire-place, has a circular hole in the centre covered with a grate, through which the flame paſſes from the fire-place into the furnace, being afterwards reverberated from the arched ſides and roof to the melting-pots, and paſſing out with the ſmoke through the top of the dome, which is lengthened into a chimney for the ſpace of a few feet. The ſecond partition divides this from the leer or annealing furnace; through the boccas, or working holes, when there are more than one, the metal is taken out of the pots, and the pots put into the furnace: theſe boccas are ſtopped with moveable covers, made of lute and brick to ſcreen the eyes of the workmen from the fire; and ſometimes on each ſide of the bocca is a boccarella, out of which coloured glaſs, or finer metal is taken from the piling-pot. To the furnace likewiſe occaſionally belong ovens, or holes near the leer, for the calcining of tartar, iron, &c.

The leer, which ſerves to anneal and cool the veſſels, and which Agricola makes a particular furnace, conſiſts of a tower, beſides the leer; the tower lies directly over the melting furnace, with a partition betwixt them about a foot thick, having an aperture called *occhio*, or *lumella*, through which the flame or heat aſcends out of the furnace into the tower: on the floor or bottom of this tower, the veſſels, faſhioned by the artiſt, are ſet to be annealed; and as the flame has here a leſs degree of intenſity than that which is ſuſtained by the pots, the veſſels, after they have been formed, cool ſlowly and gradually. This has uſually two boccas, or mouths, by which the glaſſes are put in with a fork, and placed on the floor. The *leer* is an avenue, five or ſix yards long, continued to the tower; through this the glaſſes, when annealed, are drawn in iron pans, called *fraches*, by which they come to cool by degrees, being quite cold by the time they reach the mouth of the leer, which enters the "ſaroſel," or room where the glaſſes are to be ſet.

The *third* is the "green-glaſs furnace," which is a kind of compound of all the former. It is made ſquare, (the two former being circular,) having an arch at each angle for annealing and cooling the glaſſes. The metal is wrought on two oppoſite ſides, and on the other two they have their calcars, into which are made linnet-holes for the fire to come from the furnace, to bake the frit, and alſo to diſcharge the ſmoke. Fires are made in the arches to anneal the veſſels, ſo that the whole proceſs is done in one furnace. The materials with which the inſides of theſe furnaces are conſtructed are not ordinary brick (which would ſoon melt down into glaſs, as would alſo all the ſofter ſtones,) but hard and ſandy kinds, called by Imperatus "pyramachia." But when bricks are uſed, they ſhould be formed of an earth which poſſeſſes in the higheſt degree the qualities of denſity and infuſibility, for reſiſting the fire, which continues to act upon them, without ceſſation for a long time; as the fires in a glaſs-houſe are ſeldom ſuffered to go out, from the time when the furnace is firſt employed till it needs repair, and the interval may be two or three years; the walls of the furnace, for this reaſon, as well as the pots, are conſtructed chiefly of clay, mixed with ſand, and other materials of a refractory kind, in due proportion. See Glass-*pots*.

Glass *of lead*, a glaſs made with the addition of a large quantity of lead, of great uſe in the art of making counterfeit gems. The method of making it is this: put a large quantity of lead into a potter's kiln, and keep it in a ſtate of fuſion with a moderate fire, till it is calcined to a grey looſe powder: then ſpread it in the kiln, and give it a greater heat, continually ſtirring it to keep it from running into lumps; continue this ſeveral hours, till the powder become of a fair yellow; then take it out and ſift it fine: this is called calcined lead.

Take of this calcined lead fifteen pounds, and cryſtalline, or other frit, twelve pounds; mix theſe as well as poſſible together; put them into a pot, and ſet them in the furnace for ten hours; then caſt the whole, which will be now perfectly melted, into water; ſeparate the looſe lead from it, and return the metal into the pot; and after ſtanding in

fusion twelve hours more, it will be fit to work. It is very tender and brittle, and must be worked with great care, taking it slowly out of the pot, and continually wetting the marble it is wrought upon. Neri.

It is well known, that cerus, or white lead, minium, litharge, and all the other preparations and calces of lead, are easily fused by a moderate fire, and formed into a transparent glass of a deep yellow colour. But this glass is so penetrating and powerful a flux, that it is necessary to give it a greater consistence, in order to render it fit for use. With this view, two parts of calx of lead, *e. g.* minium, and other parts of sand, or powdered flints, may be put into a crucible of refractory clay, and baked into a compact body. Let this crucible, well closed with a luted lid, be placed in a melting furnace, and gradually heated, for an hour, or an hour and a half; and afterwards let the heat be increased, so as to obtain a complete fusion, and continued in that state for the same time: let this crucible remain to cool in the furnace, and when it is broken, a very transparent yellow-coloured glass will be found in it. Some add nitre and common salt to the above mixture, because these salts promote the fusion and the more equal distribution of the sand. This glass of lead has a considerable specific gravity, and its lowest part is always the heaviest. It is an important flux in the assays of ores to facilitate their scorifications.

Glass of lead is capable of all the colours of the gems in very great perfection. The methods of giving them are these: for green, take polverine frit twenty pounds, lead calcined sixteen pounds; sift both the powders very fine; then melt them into a glass, separating the unmixed lead, by plunging the mass in water; after this return it into the pot, and add brass thrice calcined six ounces, and one pennyweight of crocus martis made with vinegar; put this in at six different times, always carefully mixing it together; let it finally settle an hour, then mix it together, and take a proof of it; when the colour is right, let it stand eight hours, and then work it. If instead of the calcined brass the same quantity of the caput mortuum of the vitriolum veneris be used, the green is yet much finer.

For topaze-colour take crystal frit fifteen pounds, calcined lead twelve pounds; mix them well together, by sifting the powders through a fine sieve; then set them in a furnace not too hot, and separate the superfluous unmixed lead, by casting the whole into water: repeat this twice; then add half gold yellow glass, and let them incorporate and purify, and they will be of the true and exact colour of the original topazes.

For sea-green, take crystal frit sixteen pounds, calcined lead ten pounds; mix and sift them together, and set them in a pot in a furnace: in twelve hours the whole will be melted; then cast it into water and separate it from the loose lead; put them into the furnace again for eight hours; then separate the loose lead by washing a second time, and return it to the pot for eight hours more. Neri. See Gems.

Glass, *Painting in*. The primitive manner of painting in glass was very simple, and of consequence very easy: it consisted in the mere arrangement of pieces of glass of different colours, in some sort of symmetry; and constituted a kind of what we call *Mosaic work*.

Afterwards, when they came to attempt more regular designs, and even to represent figures raised with all their shades, their whole address went no farther than to the drawing the contours of the figures in black, with water colours, and hatching the draperies, after the same manner, on glasses of the colour of the object intended to be painted. For the carnations, they chose glass of a bright red; upon which they designed the principal lineaments of the face, &c. with black.

At last the taste for this sort of painting being considerably improved, and the art being found applicable to the adorning of churches, basilicas, &c. they found means of incorporating the colours with the glass itself, by exposing them to a proper degree of fire, after the colours had been laid on.

A French painter at Marseilles is said to have given the first notion hereof, upon going to Rome, under the pontificate of Julius II. But Albert Durer, and Lucas of Leyden, were the first that carried it to any height.

The colours used in painting on glass are very different from those used either in painting in oil, or water.

The *black* is made of two-thirds of flakes, or scales of iron, beaten up, and mixed with another third of rocaille, or little glass beads. *White*, with sand, or little white pebbles, calcined, pounded in a mortar, and afterwards ground on marble; with one fourth-part of salt-petre, added thereto, and the mixture calcined and pulverized over again: to which, when they are ready to use it, is added a little gypsum, or plaster of Paris well ground, &c. For *yellow*, they use leaf-silver ground, mixed up in a crucible, with sulphur or salt-petre; then well beaten and ground on a porphyry stone; and, at length, ground over again with nine times as much red ochre. *Red* is made of litharge of silver, and scales of iron, gum Arabic, ferretta, glass-beads, and blood-stone, nearly in equal quantities. This is one of the most difficult colours, and the preparation only to be learned by experience. *Green* is made of æs ustum, one ounce; as much black lead, and four ounces of white sand, incorporated by the fire. After calcination, they add a fourth part of salt-petre: after a second calcination, a sixth part more: after which they make a third coction before it is used. *Azure*, *purple*, and *violets*, are prepared like green, only leaving out the æs ustum, and in the lieu thereof using sulphur for azure; perigueux for purple; and both these drugs for violet. *Carnations* are made of ferretta and rocaille. And lastly, colours for the hair, trunks of trees, &c. are made of ferretta, rocaille, &c.

This account of colours we have from M. Felibien's excellent work Des Principes d'Architecture, &c. though it must be owned, that all the painters on glass do not use them; there being few artists of that kind but have invented their own particular ones, whereof they usually make great secrets. But this is certain, that these above described are sufficient for the best paintings of all sorts; provided the person has but the skill to manage them.

In the windows of divers ancient churches, chapels, colleges, &c. we meet with the most beautiful and lively colours imaginable; such as far exceed any used among us: but it is not that the secret of making those colours is lost; but that the moderns would not go to the expence of them; nor take all the necessary pains; because this sort of painting is not now so much esteemed as formerly.

Mr. Walpole, in his Anecdotes of painting in England, has traced the history of this art from the reformation, when misguided zeal destroyed most of the monuments of it in our churches, through a series of professors to the present time. Among the later proficients in this art were Isaac Oliver, who painted the windows at Christ-church, Oxford, in 1700; William Price, who in the same year painted the windows in Merton chapel; William Price, the son, to whose art we owe the windows at Queen's, New-college, and Maudlin, of whom Mr. Walpole says, that his colours are fine, his drawing

good, and his tafte in ornaments and Mofaic far fuperior to any of his predeceffors, and equal to the antique. In 1761, Mr. Paterfon, an auctioneer late of Effex-houfe in London, exhibited the two firft auctions of painted glafs imported from Flanders; and undertook alfo to eftablifh a manufacture of painted glafs: feveral of the pieces of this ingenious artift exhibited colours vying in perfection with the old paintings.

Thofe beautiful works, among the painters in glafs, which were made in the glafs-houfe, were of two kinds: in fome, the colour was diffufed through the whole body of glafs; in others, which were the more common, the colour was only on one fide, fcarce penetrating within the fubftance above one-third of a line; though this was, more or lefs, according to the nature of the colour; the yellow being always found to enter the deepeft.

Thefe laft, though not fo ftrong and beautiful as the former, were of more advantage to the workmen; becaufe, on the fame glafs, though already coloured, they could fhew other kinds of colours, where there was occafion to embroider draperies, enrich them with foliages, or reprefent other ornaments of gold, filver, &c.

In order to this, they made ufe of emery; grinding, or wearing down the furface of the glafs, till fuch time as they were got through the colour, to the clear glafs: this done, they applied the proper colours on the other fide of the glafs. By this means the new colours were prevented from running and mixing among the former, when the glaffes came to be expofed to the fire, as will hereafter be fhewn.

When the intended ornaments were to appear white, or filvered, they contented themfelves to bare the glofs of its colour with emery, without applying any new colour at all; and it was in this manner that they wrought the lights and heightenings on all kinds of colours.

The painting with vitreous colours on glafs depends entirely on the fame principles as painting in enamel; and the manner of executing it is likewife the fame; except that in this the tranfparency of the colours being indifpenfibly requifite, no fubftances can be ufed to form them but fuch as vitrify perfectly: and, therefore, the great object is to find a fet of colours, which are compofed of fuch fubftances, as, by the admixture of other bodies, may promote their vitrification and fufion; are capable of being converted into glafs; and melting, in that ftate, with lefs heat than is fufficient to melt fuch other kinds of glafs as may be chofen for the ground or body to be painted; to temper thefe colours, fo as to make them proper to be worked with a pencil; and to burn or reduce them by heat, to a due ftate of fufion, without injuring or melting the glafs which conftitutes the body painted. The firft thing to be done, in order to paint on glafs, in the modern way, is to defign, and even colour, the whole fubject on paper. Then they make choice of pieces of glafs proper to receive the feveral parts, and proceed to divide or diftribute the defign itfelf, or the paper it is drawn on, into pieces fuitable to thofe of glafs; having always a view that the glaffes may join in the contours of the figures, and the folds of the draperies; that the carnations and other finer parts may not be damaged by the lead wherewith the pieces are to be joined together.

The diftribution being made, they mark all the glaffes, as well as papers, with letters, or numbers, that they may be known again; which done, applying each part of the defign on the glafs intended for it, they copy or transfer the defign upon this glafs, with the black colour, diluted in gum-water; by tracing and following all the lines and ftrokes, as they appear through the glafs, with the point of a pencil.

When thefe firft ftrokes are well dried, which happens in about two days, the work being only in black and white, they give it a flight wafh over, with urine, gum Arabic, and a little black; and this feveral times repeated, according as the fhades are defired to be heightened; with this precaution, never to apply a new wafh, till the former is fufficiently dried. This done, the lights and rifings are given, by rubbing off the colour in the refpective places, with a wooden point or the handle of the pencil.

As to the other colours above-mentioned, they are ufed with gum-water, much as in painting in miniature; taking care to apply them lightly, for fear of effacing the outlines of the defign; or even, for the greater fecurity, to apply them on the other fide, efpecially yellow, which is very pernicious to other colours, by blending therewith.

And here too, as in pieces of black and white, particular regard muft be always had, not to lay colour on colour, or lay on a new lay, till fuch time as the former are well dried. It may be added, that the yellow is the only colour that penetrates through the glafs, and incorporates therewith by the fire; the reft, and particularly the blue, which is very difficult to ufe, remaining on the furface, or at leaft entering very little. When the painting of all the pieces is finifhed, they are carried to the furnace or oven, to anneal or bake the colours. The furnace here ufed is fmall, built of brick, from eighteen to thirty inches fquare: at fix inches from the bottom is an aperture, to put in the fuel, and maintain the fire. Over this aperture is a grate, made of three fquare bars of iron, which traverfe the furnace, and divide it into two parts. Two inches above this partition is another little aperture, through which they take out pieces, to examine how the coction goes forward.

On the grate is placed a fquare earthen pan, fix or feven inches deep; and five or fix inches lefs, every way, than the perimeter of the furnace. On one fide hereof is a little aperture, through which to make the trials, placed directly oppofite to that of the furnaces deftined for the fame end.

In this pan are the pieces of glafs to be placed in the following manner; firft, the bottom of the pan is covered with three ftrata, or layers of quicklime, pulverized; thofe ftrata being feparated by two others, of old broken glafs: the defign whereof is to fecure the painted glafs from the too intenfe heat of the fire. This done, the glaffes are laid horizontally on the laft, or uppermoft, layer of lime.

The firft row of glafs, they cover over with a layer of the fame powder an inch deep; and over this they lay another range of glaffes: and thus alternately, till the pan is quite full; taking care that the whole heap always ends with a layer of the lime-powder.

The pan thus prepared, they cover up the furnace with tiles, on a fquare table of earthen-ware, clofely luted all round; only having five little apertures, one at each corner, and another in the middle, to ferve as chimnies.

Things thus difpofed, there remains nothing but to give the fire to the work. The fire for the two firft hours muft be very moderate; and muft be increafed in proportion as the coction advances, for the fpace of ten or twelve hours; in which time it is ufually completed. At laft,

the fire, which at firſt was only of charcoal, is to be of dry wood: ſo that the flame covers the whole pan, and even iſſues out at the chimnies.

During the laſt hours, they make aſſays from time to time, by taking out pieces laid for that purpoſe, through the little aperture of the furnace, and pan, to ſee whether the yellow be perfect, and the other colours in good order. When the annealing is thought ſufficient, they proceed with great haſte to extinguiſh the fire, which otherwiſe would ſoon burn the colours, and break the glaſſes. See PAINTING.

GLASS, *painting on, by means of prints.* See BACK-*painting.*

GLASS, *poliſhing of.* See POLISHING and GRINDING.

GLASS-*porcelain*, the name given by many to a modern invention of imitating the china-ware with glaſs. The method given by M. Reaumur, who was the firſt that carried the attempt to any degree of perfection, is delivered by that gentleman in the Memoirs of the Academy of Sciences of Paris, to this effect. This change of glaſs was firſt taken notice of by Neumann, who, in diſtilling milk in a glaſs retort, obſerved, that the bottom of the veſſel acquired the appearance of porcelain, which he attributes to the fine white earthy matter of the milk forced into the glaſs by heat. Neum. Chem. Works by Dr. Lewis, p. 571.

The mixing of glaſs reduced to powder, with other leſs eaſily vitrifiable ſubſtances for forming a paſte, to be afterwards made into a ſort of a porcelain, has been a contrivance long practiſed, but it is very troubleſome, and the reſult ſubject to many faults; but this new ware is made of glaſs alone, and that with much leſs trouble, and without the reducing it to powder. By this art, veſſels of glaſs are changed into veſſels of a ſort of porcelain, without altering their form, and the meaneſt glaſs made only of ſand, lime, and ſaline aſhes, ſerves as well as the beſt for that purpoſe: our common coarſe green quart-bottles, or the great bell glaſſes with which gardeners cover their melons, &c. being by this means changeable into a beautiful white ſort of porcelain ware; and this is to be done in ſo eaſy a manner, and with ſo ſmall expence, that it requires no more trouble or charge, than that of baking a common veſſel of our coarſe earthen-ware; and for this reaſon the veſſels of this ſort of ware may be afforded extremely cheap.

It is very certain, that all porcelain ware is a ſubſtance in the ſtate of ſemi-vitrification: and in order to bring glaſs, which is a wholly vitrified ſubſtance, into the condition of porcelain, there requires no more than to reduce it to a leſs perfectly vitrified ſtate.

The queſtion which would naturally be ſtarted on this occaſion, is, whether it be poſſible to reduce glaſs to a leſs vitrified ſtate, it having already undergone what is eſteemed the laſt change by fire. But when we conſider, that the maſs of antimony, the vitrifications of many of the metals, as the glaſs of lead, and the counterfeit gems coloured by the metals, are more or leſs eaſily reduced again by chemiſtry to metals, &c. the reducing of ſand, flints, &c. after they are vitrified, at leaſt a little way back toward their native or priſtine ſtate, may appear not wholly impracticable, and the attempts which M Reaumur made on this occaſion, were what gave him the firſt hints of the glaſs-porcelain; called from his name "Reaumur's porcelain."

The method of making it is this. The glaſs veſſels to be converted into procelain are to be put into a large earthen veſſel, ſuch as the common fine earthen diſhes are baked in, or into ſufficiently large crucibles; the veſſels are to be filled with a mixture of fine white ſand, and of fine gypſum or plaſter-ſtone burnt into what is called plaſter of Paris, and all the interſtices are to be filled up with the ſame powder, ſo that the glaſs veſſels may no where touch either one another, or the ſides of the veſſel they are baked in. The veſſel is to be then covered down and luted, and the fire does the reſt of the work; for this is only to be put into a common potter's furnace, and when it has ſtood there the uſual time for the baking of the other veſſels, it is to be taken out, and the whole contents will be found no longer glaſs, but converted into a white opaque ſubſtance, which is a very elegant porcelain, and has almoſt the properties of that of China. Memoirs Acad. Sciences Par. 1739.

The powder which has ſerved once, will do again as well as freſh, and that for a great many times: nay, it ſeems, ever ſo often. The cauſe of this transformation, ſays Macquer, is probably that the vitriolic acid of the gypſum quits its baſis of calcareous earth, and unites with the alkaline ſalt and ſaline earth of the glaſs, with which it forms a kind of ſalt or ſelenites, differing from the calcareous ſelenites, by the interpoſition of which matter the glaſs acquires the qualities of porcelain. Dr. Lewis, from a variety of experiments on the nature and qualities, and method of producing this porcelain, has deduced the following concluſions: 1. Green glaſs cemented with white ſand received no change in a heat below ignition: in a low red-heat, the change proceeded very ſlowly; but in a ſtrong red-heat, approaching to whiteneſs, the thickeſt pieces of glaſs bottles were thoroughly changed in three hours. 2. The glaſs ſuſtained the following progreſſion of changes. Its ſurface firſt became blue; its tranſparence was diminiſhed, and when held between the light and the eye, it appeared of a yellowiſh hue: afterwards it was changed a little way on both ſides into a white ſubſtance, externally ſtill blueiſh: and as this change advanced ſtill farther and farther within the glaſs, the colour of the vitreous part in the middle approached nearer to yellow: the white coat was of a fine fibrous texture, and the fibres were diſpoſed nearly parallel to one another, and tranſverſe to the thickneſs of the piece: by degrees the glaſs became throughout white and fibrous, the external blueiſhneſs at the ſame time going off, and being ſucceeded by a dull whitiſh or dun colour: by a ſtill longer continuance in the fire, the fibres were changed gradually from the external to the internal part, and converted into grains; and the texture then was not unlike that of common porcelain. The grains, at firſt fine and ſomewhat gloſſy, appeared afterwards larger and duller, and at length the ſubſtance of the glaſs became porous and friable, like a maſs of white ſand ſlightly cohering. 3. Concerning the qualities of the converted glaſs Dr. Lewis obſerves, that the whiteneſs of the internal part was not inferior to that of porcelain, but that its ſurface was the leaſt beautiful; that the thick pieces were quite opaque, and that ſeveral thin pieces were ſemi-tranſparent: that while it remained in a fibrous ſtate, its hardneſs became greater than that of glaſs, or of the common kinds of porcelain; it was capable of ſuſtaining ſudden changes of heat and cold better than any porcelain; and in a moderate white heat, it was fuſible into a ſubſtance not fibrous, but vitreous and ſmooth, like white enamel: that when its texture had been coarſely granulated, it was now much ſofter and unfuſible; and, laſtly, that when ſome coarſely granulated unfuſible pieces which, with the continuance of a moderate heat, would have become porous and friable, were ſuddenly expoſed to an intenſe fire, they were rendered remarkably more compact than before; the ſolidity of ſome of them being ſuperior to that of any other ware. 4. No differences appeared in the internal colour, hardneſs, texture, or the regular ſucceſſion of changes, from the uſe of different cementing ſubſtances;

though in external appearances the differences were considerable. All the pieces which had been surrounded with charcoal or with soot were externally of a deep black colour, which did not disappear by exposure to a strong fire during an hour, with free access of air. Coloured clays and sands communicated different shades of a brown colour; and white earths gave whitish, greyish, or brownish tinges. White sand, calcined flints, and gypsum, gave in general the greatest whiteness, and tobacco-pipe clay the greatest glossiness and brightness. Glasses composed of earths without alkaline salt, glass of lead, flint-glass, crown-glass, looking-glass plates, a glass prepared with calcined flints and a fixed alkaline salt, and even green glass which had been fused together with a ninth part of alkaline salt, suffered none of the above alterations by cementation. Green bottle-glass and common window-glass were most susceptible of these alterations. 6. The changes produced by cementation could not proceed from any absorption of matter from the cementing substance; because no increase of weight was given, and because the same changes were produced upon a piece of glass merely by heat, without any cementing substance. See Com. Phil. Techn. p. 230—255.

Mr. Gregory Watt, in his valuable paper on basalt (Phil. Trans. for 1804, cited by Aikin,) alleges this porcellanous change of glass as an illustration of his important principle, *viz.* "that bodies whose fibres have a natural tendency to a crystalline arrangement, or a polarity, when vitrified by a sufficient heat and cooled hastily in the vitreous state, are able subsequently to return to their natural crystalline arrangement of fibre, when exposed to a heat merely sufficient to soften the texture, though not enough for fusion. This, in the instance of basalt, he shews by the singular crystallizations formed in the cells of fused basalt, long after it had lost the liquidity of fusion. The circumstance of no material change occurring in the weight of glass by this conversion into the fibrous state, shews incontestably that it cannot be owing either to any thing gained during the process, nor to any material loss of the alkali; and this is also rendered manifest by its return to the vitreous state and vitreous qualities when again melted. This too may again be porcellanized in the same way, and again be melted into glass, and so on alternately." See PORCELAIN.

GLASS-*pots*, the vessels in the glass manufacture used for melting the glass. Those for the white glass works are made of a tobacco-pipe clay, brought from the Isle of Wight, which is first well washed, then calcined, and afterwards ground to a fine powder in a mill; which being mixt with water, is then trod with the bare feet till it is of a proper consistence, to mould with the hands into the proper shape of the vessels. When these are thus made, they are afterwards annealed over the furnace. Those for the green-glass work are made of the nonsuch, and another sort of clay from Staffordshire; they make these so large as to hold three or four hundred weight of metal. And besides these, they have a small sort called piling pots, which they set upon the larger, and which contain a finer and more nice metal fit for the nicest works. Neri.

The clay that is used for this purpose should be of the purest and most refractory kind, and well cleansed from all sandy, ferruginous, and pyritous matters; and to this it will be proper to add ground crucibles, white sand, calcined flints duly levigated, or a certain proportion of the same clay baked, and pounded not very finely. The quantity of baked clay that ought to be mixed with the crude clay, to prevent the pots from cracking when dried, or exposed to a great heat, is not absolutely determined, but depends on the quality of the crude clay, which is more or less fat. M. D'Antic, in a memoir on this subject, proposes the following method of ascertaining it: the burnt and crude clay, being mixed in different proportions, should be formed into cakes, one inch thick, and four inches long and wide. Let these cakes be slowly dried, and exposed to a violent heat, till they become as hard and as much contracted as possible, and in this state be examined; and the cake, he says, which has suffered a diminution of its bulk equal only to an eighteenth part, is made of the best proportions. He observes, in general, that most clays require that the proportion of the burnt should be to the fresh as four to five.

It is of great importance that the material of which the pots are made should be carefully selected, as they are exposed to the action of a very fierce fire, and also to the solvent activity of the glass with its powerful fluxes. They should also be made very thick and strong, as they are intended to last for many months. When finished, they are placed in a warm room in order to discharge their moisture, and any small fissures arising from the unequal shrinking of the clay are closed by gently beating with a mallet. They are afterwards gradually heated in a small oven, constructed for this purpose, and slowly brought to a red heat; and after remaining for some time in this state, they are removed to the furnace, and fixed down in their places by fire-clay. Here, on account of a further shrinking, they remain for a day or two before they are fit for receiving the glass materials. Pots of this kind are said to last, at an average, about a year.

GLASS *Tubes* are of various lengths, diameters, and forms, according to the purposes to which they are applied. These are often formed with the lamp and blow-pipe, in the manner described under the article LAMP-*blowers*. In this way tubes are sealed hermetically (see HERMETICAL *Seal*), tubes are bent, others are joined, bulbs are annexed to tubes for thermometers, &c., and glass is drawn out into threads.

It has been observed, that glass tubes laid before the fire in an horizontal position, and with their extremities supported, have had a rotatory motion about their axes; and also a progressive motion towards the fire, even when their supports are inclined from the fire, so that the tubes will move a little upwards. See Phil. Trans. N° 476. § 1.

When the progressive motion of the tube is stopped by any obstacle, its motion about its axis will still continue. When the tubes are placed in a nearly upright posture leaning to the right hand, the motion will be from east to west; but if they lean to the left, the motion will be from west to east; when the nearer they are placed to the perfectly upright posture, the less the motion will be either way.

If the tube be placed horizontally on a glass plane, the fragment, for instance, of coach window-glass, instead of moving towards the fire, will move from it, and about its axis, in a contrary direction to what it had done before. Nay, it will recede from the fire and move a little upwards, when the plane inclines towards the fire.

Neither the draught of air up the chimney, not attraction or repulsion, are the cause of these phenomena. It seems rather owing to the swelling of the tube towards the fire; for allowing such swelling, gravity must pull the tube down, when supported near its extremities horizontally; and a fresh part being exposed to the fire and swelling out again, must fall down again, and so on successively; which will produce a rotatory motion towards the fire.

If the tube be supported by two other tubes, and these be brought near to each other, and to the centre of the supported tube, then its parts hanging over on each side, being larger than the part which lies between the supporters, will,

by their weight, pull downwards, and consequently force the middle part, resting upon its two props, upwards: and being less advanced towards the fire, as being less heated, will, by their oblique situation, pull the middle part backwards also from the fire, which will cause a rotatory regressive motion, quite contrary to what the tube had when supported near its extremities. And when a single tube lies inclining opposite to the fire, either to the right hand or to the left, out of a plane perpendicular to the surface of the fire, gravity will not permit the curved part to rest, but pull it down till it coincides with a plane perpendicular to the horizon; and consequently, as new curves are generated, new motions will be so too; that is, the tube will be made to move about its axis, with this difference, when the tube inclines to the right hand, the motion will be from east to west; when to the left hand, from west to east. The justness of this reasoning is made manifest, by bending a wire, and supporting it first near its extremities, then near its centre on each side, afterwards inclining it to the right and to the left; the bending in every case representing the curved part of the tube next the fire. This solution of the phenomena is rendered the more probable from hence, that when four supporters were made use of, one at each extremity, and two near the middle, there was no motion at all, either backward or forward. Nor does the increase of contact hinder the motion, because the plate of glass was so broad as to have a much greater contact with the tube, and yet both the rotatory and regressive motions were manifest.

These experiments succeeded best with tubes about twenty or twenty-two inches long; the diameter about one-tenth of an inch: and they had in each a pretty strong pin fixed in cork, for an axis to roll with on the supporting tubes. Phil. Transf. N° 476.

Glass *receivers, how to cement the cracks of.* See Cæment and Receiver.

Glass, *how to take the impression of antique gems in.* See Gem.

The property which glass possesses in common with other substances of being expanded by heat, and contracted by cold, was long ago observed and evinced by Mr. Hook. See Birch's Hist of the Royal Society, vol. i. p. 411. See Thermometer.

Glass, *Laws relating to.* No glass shall be imported into Ireland, other than the manufacture of Great Britain, on pain of forfeiting the same, and ship, and 10*s.* a pound. 19 G. II. c. 12. If any foreign glass shall be landed or unshipped before entry and payment of the duties, or without warrant from the proper officer, the same shall be forfeited, or its value; and the master or other person having command of the vessel, and every other person concerned in such landing or unshipping, shall forfeit 100*l.* 17 G III. c. 39. And by 38 G. III. c. 33. for preventing the fraudulent importation of glass, every package containing any plate or plates of glass unframed, being *plate, crown,* or *sheet* glass, which shall be imported, or brought into this kingdom for exportation, shall be marked on the outside in Roman letters four inches long at least, with the word Glass, on pain of forfeiture, together with the package, and all goods contained in it. The master of the vessel importing such package, shall, in reporting his cargo, express every such package of glass, on pain of forfeiting the same, and also 100*l.* Nor shall any such package be imported, which shall not contain 500 weight, on pain of forfeiture; but not extending to any plate of glass 60 inches in length or upwards, on account of the package not being marked. By 43 G. III. c. 69. For every 100 weight of materials, &c. that shall be made use of in Great Britain for the making of *plate* or *flint glass*, or *enamel, stained,* or *paste glass*, or *phial glass*, shall be paid by the maker thereof 1*l.* 12*s.* 8*d.*; for every hundred weight of materials used in making *spread window glass*, commonly called *broad glass*, 8*s.* 2*d.*; for every hundred weight of materials used for making all other *window glass* (not being spread glass), whether flashed, or otherwise manufactured, commonly called *crown glass*, or *German sheet glass*, 1*l.* 4*s.* 6*d.*; for every hundred weight of materials used in making *common bottles* (not being phials), and of vessels used in *chemical laboratories*, and of *garden glasses*, and of all other vessels or utensils made of common bottle metal, 4*s.* 1*d.*; and for every hundred weight of plate glass, and of all other glass manufactures, which shall be imported into Great Britain, the same not being flasks, in which wine or oil is imported, nor foreign green glass bottles, nor Irish glass, or glass manufactures imported directly from Ireland, to be paid by the importer before the landing thereof, 2*l.* 2*s.* And any glass-maker shall take out a licence, for which he shall pay 10*l.*, to be renewed annually ten days at least before the end of the year, on the penalty of 50*l.* 24 G. III. c. 41. 43 G. III. c. 69. The place of making glass shall be entered, before the commencement of manufacture, and all work-houses, furnaces, pots, annealing arches, &c. &c. on pain of forfeiting 200*l.* 19 G. II. c. 12. 17 G. III. c. 39. 35 G. III. c. 114. Officers may enter and survey, and mark pots; and any person counterfeiting or altering such mark, or conniving at its being done, shall forfeit 500*l.*; or defacing, or causing to be defaced or obliterated such mark, incurs a forfeiture of 200*l.* 35 G. III. c. 114. Notice of beginning to work shall be given in writing, on pain of forfeiting 20*l.* 19 G. II. c. 12. And notice of filling every pot shall be given twelve hours before the operation is begun, on pain of 50*l.* 19 G. II. c. 12. 17 G. III. c. 39. Annealing arches are to be made of a certain form, and numbered, on pain of forfeiting 100*l.* Annealing arches are to be locked, except at certain times; and breaking such lock, &c. incurs a forfeiture of 200*l.* 35 G. III. c. 114. The same act comprehends several other provisions, enforced by certain penalties. Bottles are not to be removed till they are weighed, (penalty 100*l.*) which are to be kept separate from those that are unweighed, on pain of forfeiting 50*l.* No phials, &c. are to be made in places entered for making common glass bottles, on pain of forfeiting 200*l.* Entry shall be made of the glass manufactured every month within the bills, and elsewhere every six weeks, on pain of 20*l.* The maker, within the bills, shall, in four weeks, and elsewhere in six weeks after entry, pay off the duties, on pain of double duty. If glass, shipped for exportation, shall be re-landed, it shall be forfeited, and every person concerned therein shall forfeit 100*l.* 17 G. III. c. 39. For the drawbacks on exportation of glass, see 43 G. III. c. 69. Obstructing officers in securing the duties incurs a forfeiture of 50*l.* 19 G. II. c. 12. 17 G. III. c. 39. Penalties are appropriated, half to the use of the king, and half to him that shall sue.

Glauber

GLAUBER, JOHN RODOLPH, in *Biography*, a celebrated chemist of Amsterdam, who was esteemed the Paracelsus of his age, was born in Germany in the beginning of the sixteenth century. He travelled much in the pursuit of chemical knowledge, and collected many secret processes; and his experiments contributed to throw much light on the composition and analysis of the metals, inflammable substances, and salts. In fact he passed the greater part of his life in the laboratory. He did not always see the proper application of his own experiments, and vainly fancied that he had discovered the panacea, and the philosopher's stone, which were at that time objects of pursuit: and the disappointment of many persons, who had been seduced by his promises, contributed to bring the art of chemistry into contempt. His theory is full of obscurity; but his practice has perhaps been misrepresented by those who listened to his vain and pompous pretensions; and who accuse him of a dishonourable traffick, in first selling his secrets to chemists at an enormous price, of again disposing of them to other persons, and lastly, of making them public in order to extend his reputation. Glauber published about twenty treatises; in some of which he appears in the character of physician, in others in that of an adept or metallurgist; in the latter he most particularly excelled. However, it would be unjust not to give him the praise of acuteness of mind, of facility and address in the prosecution of his experiments, and of extensive chemical knowledge. He was the inventor of a salt, which to this day retains his name in the shops of our apothecaries. The works of Glauber have appeared in different languages; the majority of editions are in German, some in Latin, and others in French. A collection of the whole in Latin was published at Frankfort in 1658, in 8vo. and again 1659 in 4to. An English translation was published by Christopher Pack, London, 1689, in folio. Eloy. Dict. Hist.

GLAUBER *Salt, native* or *natural*, in *Mineralogy*, the sulphat of soda of chemists, was discovered by baron Born in the salt mines of Upper Austria; after which Monnet Volta, Suckow, Gmelin, Breislak, Pallas, and others have added to the list of the localities of this saline substance, which is more frequently found in a native state than has been supposed by some writers. It generally occurs as mealy efflorescence; sometimes massive, seldom stalactitical or crystallized: in which latter case the crystals are described as acicular and as six-sided prisms, more or less flatly acuminated by three planes, set on the lateral edges, or sometimes on the lateral planes: they are shining: their internal lustre is vitreous. Fracture of the crystals small conchoidal. It varies from transparent to opaque according to its freshness. It is brittle. Its taste is a mixture of salt and bitter. Besides in the above forms, it occurs also, and most frequently, dissolved in certain mineral waters, in the neighbourhood of salt mines and salt lakes, where also the efflorescence is mostly found on moorish ground, sand stone, marle slate, and new walls. For the chemical character of this salt, see SODA, *Sulphat of*.

Brongniart has given the most complete list of the localities of Glauber salt. In solution it occurs in the waters of several lakes of Austria and Lower Hungary, especially in that of Neusiedel, between the counties of Oedenburg and Wieselburg. It is met with in Switzerland; in Spain, round a source in the neighbourhood of Aranjuez, and near Vacia-Madrid, as efflorescence, at the bottom of a ravine: the source which issues from the ravine contains a great proportion of this salt. Also the water of the Tagus is said to hold it in solution. In France it has been found near Grenoble. The steep sides of the Solfatara of Pouzzole yield this salt, in one place, on the north side. It is common in the lakes of Siberia; and it has been observed that the bottom of the lake Gunifkoi, between Toïon and Ilynskoy, is covered with a crust of Glauber salt as soon as the temperature is below the freezing point. Pallas tells us that the apothecaries of Orenburg annually collect a quantity of this salt, which is deposited in autumn at the bottom of a lake between the Tobol and Mioes. It is also found in a lake near Gourief; in another between Utoiska and Miniuskaïa, in the neighbourhood of Enissey; likewise at the foot and in the middle of the chains of the Ural mountains, near Tsheliabinsk: in the last of these places, the salt issues in the spring season out of the earth in the form of efflorescence or froth. The clayey soil of that neighbourhood does not contain any Glauber salt; whence this is supposed to be formed, in the same manner as salt-petre is, at the surface of the earth, and by the action of the atmosphere. Lastly, this salt is also obtained from the alum-slate of Duttweiler, near Saarbrück, in the department of la Sarre, and from the aluminiferous waters of Freyenwalde, in Brandenburg.

Glazing

GLAZING. The Roman method of glazing ſome of their urns might give our workmen a hint toward a method greatly ſuperior to any thing now in practice for the glazing of earthen-ware. There is a ſort of red urns found in Yorkſhire, which are, inſtead of glazing, covered all over inſide and out with a fine coral-coloured varniſh, that gives them a beauty, which no earthen-ware of our times can attain; and is not only far more durable than our way of doing it with lead, which is apt to crack and fly, both with wet and with heat, but far more ſafe and wholeſome; and being well known to be a vapourable metal, and its fumes very noxious, there is great reaſon to ſuſpect that it muſt be unwholeſome when brought to the fire. This ancient glazing ſeems to have been done either by the bruſh, or elſe by dipping, for both the inſide and outſide are varniſhed with equal regularity; and ſomething may be gueſſed at as to the materials they uſed in it, from what Pliny has left us. This author occaſionally obſerves, that ſuch earthen-ware as was painted with bitumen never loſt its beauty; and afterwards, that it was a cuſtom to cover over whole ſtatues with this ſort of glazing, which he obſerves did not only make a ſmooth coat, but ſunk into the matter of the ſtone or earth, and therefore this could not be likely to crack and fly off like our lead-coats on plates, &c. which is merely a cruſt laid over them. Hook's Philoſ. Collect. p. 89.

A common glazing for any kind of earthen-ware may be made of white ſand forty pounds, of red-lead twenty pounds, of pearl-aſhes twenty pounds, and of common ſalt twelve pounds. Powder the ſand by grinding it, and then add it to the other ingredients and grind them together: after which calcine them for ſome time with a moderate heat, and when the mixture is cold, pound it to powder; and when wanted for uſe, temper it with water. The proportion of theſe ingredients may be occaſionally varied. We may obſerve, in general, that lead ought to be excluded from the compoſition of glazings, and other fluxes ſubſtituted in its ſtead. See COLICA *Dammoniorum*.

A tranſparent glazing may be prepared, without lead, by calcining forty pounds of white ſand, twenty-five pounds of pearl-aſhes, and fifteen pounds of common ſalt; and proceeding as before: and a more perfect tranſparent glazing may be made of ſand forty pounds, of wood-aſhes perfectly burnt, fifty pounds, of pearl-aſhes ten pounds, and of common ſalt twelve pounds. The following recipes are taken, for the moſt part, from Kunckel, who ſays that they are the true glazings uſed at Delft, and other Dutch manufactories.

GLAZING, *Black*, is made of eight parts of red-lead, iron filings three, copper-aſhes three, and zaffre two meaſures. This, when melted, will make a brown black; and if you want it blacker, add more zaffer to it.

GLAZING, *Blue*, is thus prepared: take lead-aſhes, or red-lead, one pound, clear ſand, or powdered flints, two pounds, common ſalt two pounds, white calcined tartar one pound, Venice or other glaſs half a pound, zaffer half a pound: mix them well together, and melt them for ſeveral times, quenching them always in cold water. If you would have it fine and good, it will be proper to put the mixture into a glaſs furnace for a day or two.

Another blue glazing may be formed of one pound of tartar, a quarter of a pound of red-lead, half an ounce of zaffer, and a quarter of a pound of powdered flints, which are to be fuſed and managed as in the laſt recipe. Or, take two pounds of calcined lead and tin, add five pounds of common ſalt, five pounds of powdered flints, and of zaffer, tartar, and Venetian glaſs, each one pound. Calcine and fuſe the mixture as before.

Or, again, take of red-lead one part, of ſand three parts, and of zaffer one part. For a violet blue glazing, take four

ounces of tartar, two ounces of red-lead, five ounces of powdered flints, and half a dram of manganefe.

Glazing, *Brown*, is made of red-lead and flints, of each fourteen parts, and of manganefe two parts, fufed: or, of red-lead twelve parts, and manganefe one part, fufed. A brown glazing, to be laid on a white ground, may be made of manganefe two parts, and of red-lead and white glafs, of each one part, twice fufed.

Glazing, *Flefh-coloured*, is made of twelve parts of lead-afhes, and one of white glafs.

Glazing, *Gold-coloured*. To make gold-coloured glazing, take of litharge three parts; of fand, or calcined flint, one part: pound, and mix thefe very well together; then run them into a yellow glafs with a ftrong fire. Pound this glafs, and grind it into a fubtile powder, which moiften with a well faturated folution of filver; make it into a pafte, which put into a crucible, and cover it with a cover. Give at firft a gentle degree of fire; then increafe it, and continue it till you have a glafs, which will be green. Pound this glafs again, and grind it to a fine powder; moiften this powder with fome beer, fo that by means of an hair pencil you may apply it upon the veffels, or any piece of earthen ware. The veffels that are painted or covered over with this glazing, muft be firft well heated, then put under a muffle; and as foon as the glafs runs, you muft fmoak them, by holding them over burning vegetables, and take out the veffels. Mr. Heinfius of Peterfburg, who fent this receipt to the Royal Society, ufes the words *afflare debes fumum*, which is rendered *fmoak them*, in the Tranfactions. Phil. Tranf. N 465. § 6.

Kunckel gives feveral preparations for a gold-coloured yellow glazing. This may be produced by fufing a mixture of three parts of red-lead, two parts of antimony, and one part of faffron of Mars; by again melting the powdered mafs, and repeating the operation four times; or, by fufing four or five times a compofition of red-lead and antimony, of each an ounce, and of fcales of iron half an ounce: or by calcining and fufing together eight parts of red-lead, fix parts of flints, one part of yellow ochre, one part of antimony, and one part of white glafs. A tranfparent gold-coloured glazing may be obtained by twice fufing red-lead and white-flints, of each twelve parts, and of filings of iron one part.

Glazing, *Green*, may be prepared of eight parts of litharge, or red-lead, eight parts of Venice glafs, four parts of brafs-duft, or filings of copper; or, of ten parts of litharge, twelve of flints or pebble, and one of *æs uftum*, or copper-afhes.

A fine green glazing may be produced by ufing one part of the Bohemian granate, one part of filings of copper, one part of red-lead, and one part of Venetian glafs; or by fufing one part of white glafs, the fame quantity of red-lead, and alfo of filings of copper; powdering the mafs, and adding one part of Bohemian granate to two parts of this powder. A fine green may be obtained by mixing and grinding together any of the yellow glazings with equal quantities of the blue glazings; and all the fhades and teints of green will be had by varying the proportion of the one to the other, and by the choice of the kind of yellow and blue.

Glazing, *Iron-coloured*, is prepared of fifteen parts of lead-afhes, or red-lead, fourteen of white fand, or flints, and five of calcined copper. This mixture is to be calcined and fufed.

Glazing, *Liver-coloured*, is prepared of twelve parts of litharge, eight of falt, fix of pebble or flint, and one of manganefe.

Glazing, *Purple-brown*, confifts of lead-afhes fifteen parts, clear-fand, or powdered flints, eighteen parts, manganefe one part, and white glafs fifteen meafures; to which fome add one meafure of zaffer.

Glazing, *Red*, is made of antimony three pounds, litharge, or red-lead, three, and ruft of iron, one; grind them to a fine powder. Or take two pounds of antimony, three of red-lead, and one of calcined faffron of Mars, and proceed as before.

Glazing, *Sea-green*, is made of five pounds of lead afhes, one pound of tin-afhes, three pounds of flint, three quarters of a pound of falt, half a pound of tartar, and half a pound of copper duft.

Glazing, *White*. A fine white glazing for earthen-ware is thus prepared: Take two pounds of lead, and one of tin; calcine them to afhes: of this take two parts, calcined flint, white fand, or broken white glafs, one part, and falt one part: mix them well together, and melt them into a cake for ufe. The trouble of calcining the tin and lead may be prevented, by procuring them in a proper ftate.

The white glazing for common ware is made of forty pounds of clear fand, feventy-five pounds of litharge, or lead-afhes, twenty-fix of pot-afhes, and ten pounds of falt: thefe are three times melted into a cake, quenching it each time in clear cold water. Or, it may be made of fifty pounds of clean fand, feventy of lead-afhes, thirty of wood-afhes, and twelve of falt.

A very fine white glazing may be obtained by calcining two parts of lead, and one part of tin; and taking one part of this mafs, and of flints and common falt, of each one part, and fufing the mixture. See Delf-*ware*.

A white glazing may be prepared by mixing one hundred pounds of mafticot, fixty-pounds of red-lead, twenty pounds of calcined tin or putty, and ten pounds of common falt; and calcining and powdering the mixture feveral times.

Glazing, *Yellow*, is prepared of red-lead, three pounds; calcined antimony and tin, of each two pounds: or, according to fome, of equal quantities of the three ingredients. Thefe muft be melted into a cake, then ground fine; and this operation repeated feveral times: or, it may be made of fifteen parts of lead-ore, three parts of litharge of filver, and fifteen parts of fand.

A fine yellow glazing may be procured by mixing five parts of red-lead, two parts of powdered brick, one part of fand, one part of the white glazings, and two parts of antimony, calcining the mixture and then fufing it. Or, take four parts of white glafs, one part of antimony, three parts of red-lead and one part of iron fcales, and fufe the mixture: or, fufe fixteen parts of flints, one part of iron-filings, and twenty-four parts of litharge. A light yellow glazing may be produced with ten parts of red-lead, three parts of antimony, and three of glafs, and two parts of calcined tin. See *Gold-coloured* Glazing.

Glazing, *Citron-yellow*, is made of fix parts of red-lead, feven parts of fine red brick-duft, and two parts of antimony. This mixture muft be calcined day and night for the fpace of four days, in the afh-hole of a glafs-houfe furnace, and at laft urged to fufion.

Glazing *of Delf-ware*. See Delf-*ware*.

Glazing *of Porcelain*. See Porcelain.

Glazing *of Stone-ware, and Queen's ware*. See Pottery.

Glazing *for Tobacco Pipes*. See Tobacco-pipes.

Glazing, in *Painting*, a term of the art, expreffive of a peculiar mode or variety in the practice of it. It confifts in laying a tranfparent colour, made very thin by a great quantity of oil, or other vehicle, over a folid body of opaque

colour; and its intent is, to give a greater degree of clearness and brilliancy to the colour produced by this process, than can be obtained by mixing together in substance the two colours thus employed. In this mode their hues are blended, without disparagement of each other; whereas, in mixing them in the ordinary way, a certain diminution of their brilliancy takes place, produced by the dissimilar nature of their qualities.

Glazing appears to have been practised very early in oil-painting; and probably the use of varnishes over pictures painted with water-colours may have first shewn its utility. Indeed it could not fail to be the case, if the varnish employed happened to be tinged with any colour; for the lustre pictures acquired by that circumstance must be strikingly engaging: a harmony and sweetness are thereby gained, which all other means are vainly employed to obtain. It is therefore surprizing that all those who practised the art of painting after the discovery of the use of oil, should not have given in to the application of it. Yet it is certain that the Roman school is remarkably deficient in the knowledge of the value of this practice, and most frequently neglected to use it; owing probably to the employment painting found in fresco. The Venetian and Dutch schools, on the other hand, employed it in perfection, and it is in their works that a knowledge of it may best be acquired.

The principal difficulty attending the use of glazing, is to avoid the too common application of it; as it does not suit the representations of all substances, in its more immediate sense; though one general glaze over a picture, completed in its forms, will at all times benefit the work; if it happens not to be too low, or insipid, in its tones of colour.

All kinds of gems and polished substances, such as metals, silks, velvets, &c. are imperfectly wrought to effect, when it is not employed; and flesh, which is in nature compounded of a great variety of colours, is seldom quite perfect in its hue, when glazing is not employed to finish with. It is a species of it, produced by the yellow varnish being but partially removed from old pictures, which gives them their peculiar and brilliant lustre. It is quite impossible to make any effect exactly like it with fresh colours, unless some artifice be used to forerun the effects of time; such as rubbing in dirt, and then partially removing it, &c. tricks which picture dealers are perfectly conversant with; and by which many an ingenious copy is passed off upon the unlearned amateur, to the enrichment of the dealer, and the future annoyance of the buyer, when time and improved information let him into the secret.

Glazing is the most valuable part of the practice of painting, when judiciously employed; as it produces clear broken tones of colour, which leave no remembrance of the pallette, but deceive the eye by the variety of hues, and dazzling effect of light, produced by one colour shining through another in different degrees of illumination; much more like the effects of natural objects, than the use of opaque colours can possibly produce. But then great dexterity and judgment are required to use it properly in so general a manner. A well-informed and scientific artist knows the tone which one colour glazed over another will produce; and without that knowledge, a dirty dulness may be the effect, instead of the clearness required: and if not successful, it is always injurious; there is no medium in the application of it. If the under colour is not improved, it is sure to be deteriorated; and it will require repainting, to restore its original freshness. So that when a painter has prepared a work for glazing, (which should always be done with great clearness and precision,) the most extreme caution is requisite in adapting the tone of the glaze which he proposes to use to the general hue of the picture before he applies it. It is not possible to give rules more explicit on this matter; the indefinite subdivisions of hues which all colours are capable of, must for ever leave to the feeling and judgment of the artist their peculiar application. It is hardly necessary to state that a glaze of red, over blue, will produce purple; of blue, over yellow, green; and of red, over yellow, orange; but it may aid the student in his practice, if he considers, that all the varieties of tone the original colours are capable of, will, when equally employed, produce a corresponding compound; and, of course, if his picture be of too red a hue, though of a light tone, a corresponding one of blue, or of yellow, will change it to the one he may require; and if he use the blue and yellow together as a green, it will produce a negative colour; totally destroying the red: but the varieties are too complicated and numerous to follow.

Glazing *of Cloth*. The process of glazing is used for all the stout fabrics of cotton goods, and sometimes for those of linen. It is a part of the general processes of finishing goods for the market, and which is carried on by those who are generally called cloth-lappers, or calender-men. The glazing is done by putting on the cloth a small quantity of white wax, such as that used in the manufacture of wax candles, and the gloss is afterwards effected by the friction of any smooth body on the surface of the cloth. By the ordinary process the apparatus is very simple, consisting merely of a smooth table, a little inclined towards the operator, like a common writing desk, upon which the cloth to be glazed is spread smoothly, and drawn over, as occasion requires, from one end of the piece to the other. Above this is a lever, suspended from any convenient fixture to the roof, the lower end hanging in contact with the cloth, and by moving this backward and forward, the necessary friction is produced. The end of the lever next to, and in contact with the cloth, is faced with a smooth piece of flint or pebble, finely polished, and of a cylindrical form, the under surface of which is in contact with the cloth. This lever being drawn backward and forward by the operator's hands, the whole cloth is polished or glazed in succession, the joint at the top of the lever being fitted into a horizontal slider, which allows the polisher or flint to be mov d from one side of the cloth to the other. In this way of glazing, the whole is performed by the power of a man's arms and hands; and, from the position of his body being constantly inclined over the table, is found to be a very laborious and fatiguing operation. The great number of people necessarily employed by this operation, and the difficulty of getting large quantities of goods rapidly glazed to answer the demands of hurried shipments for exportation, suggested lately the idea of a more speedy and efficacious manner of performing the operation of glazing by an improvement and alteration in the construction of the common five-bowl calender. This improvement was planned and executed at the extensive works of the late Mr. John Miller of Glasgow, who furnished the inventor with the means of carrying his plan into effect, and upon a proof of its efficacy on trial, his majesty's royal letters patent for its exclusive use to the inventor or his assignees within Scotland were obtained in the usual form. Two or three machines were then constructed for his own works, to which, as far as we know, they are still confined; and these machines have given the most universal satisfaction to all who have had their goods glazed by them, while at the same time an immense reduction of labour has been effected by their use.

The patent glazing machine, like the common calender, consists of five bowls, or cylinders, four of which are of

cast iron, smoothly turned, and finely polished on the surface, and the large or intermediate cylinder is generally of pasteboard on an iron axis. In the common operation of smoothing by means of the calender, the velocity of the cylinders revolving upon their own *axes*, is in the ratio of their respective diameters, so that an equal quantity of superficies is constantly exposed of each. In the glazing-calender, or machine, it is only necessary that the motions of one of the cylinders should be so much accelerated as to produce the friction necessary to effect the glazing by rubbing against the other cylinders with which it is in contact, so as not to be liable to tear or otherways injure the fabric. This motion is produced by means of wheels placed in the following manner: On the axis of the main cylinder A, is a cast iron wheel of any convenient diameter and number of teeth. This wheel works into the stud-wheel B, the number of whose teeth is not material to the speed, and whose diameter may be regulated so as to pitch well into the remaining wheels. The wheel is placed to revolve loosely on an iron stud, screwed into the frame-work of the machine. The stud-wheel B gives motion to the second stud-wheel C, and it continues the motion to the wheel D, which is fastened on the axis of the first iron cylinder. The upper cylinder works merely by friction, as in a common calender, and when the intermediate stud-wheel B is removed by being taken off the stud, the whole cylinders will revolve exactly as in the common machines, without producing any glazing effect. The simplicity of this machine, the regularity of the gloss which it gives, and the immense saving of labour, are powerful recommendations in its favour. The great quantity also which may be effected by it in a very limited time, renders it peculiarly adapted to meet the occasional exigencies of the exporter; and the additional advantage of its facility of adaptation to the purposes of the common calender, when glazing is not required, adds to its value and utility. Upon pressing occasions, one of these engines, by being constantly employed night and day, will glaze from 600 to 800 pieces of cloth, of 28 yards each, weekly.

Those employed in the late Mr. Miller's works are driven by means of a steam engine, by which also various other kinds of machinery, adapted to the various operations of the business, are set in motion Should any machinery of this description be constructed in works where there may be a general necessity of keeping them constantly employed for the purpose of glazing, it will be very necessary that care should be taken that the moving power, whether water, steam, or horses, should be ample; as it must be evident, even to those who are not practically conversant with the calculation of power and resistance, that this calender, when employed to glaze, must require considerably greater force to keep it in motion, than when the cylinders revolve in the ratios of their diameters, for the mere purpose of common calendering or smoothing.

We are not in possession of sufficient *data* to enable us to ascertain, with any tolerable precision, the quantum of resistance added by the friction; nor are we aware that any accurate experiments have been made for that purpose: but it is evident that it must be very great in all cases. It is reasonable also to infer, that it may be considerably increased or diminished by the texture or fabric of the stuff upon which the glazing operation is performed. Hence, if these machines be employed constantly in large works, and set in motion by the same power, which also drives machinery adapted to other purposes, care must be taken that the power be sufficient to effect all the various purposes to which it is applied. And should this be attempted, under the impression that the glazing might be performed by the same power as common calendering, a deficiency would be found, which must render it necessary to disengage part of the machinery, in order to give sufficient momentum to the rest. This is, perhaps, one of the most common, and at the same time, most ruinous errors into which the projectors of large works, who are not mechanics, are apt to fall. In the first instance, desirous that a large establishment should be set to work at the least possible expence, they too frequently calculate too barely, and are then obliged either to abandon their whole scheme at a great loss, to work it under serious and ruinous inconveniences, or to repair, at a triple expence, what they have left deficient at first.

Glue

GLUE, GLUTEN, a viscid, tenacious matter, serving as a cement to bind or connect divers things together.

There are divers kinds of glues made use of in the divers arts; as the common glue, glove glue, parchment glue: but the two last are more properly called *size*.

The common or strong glue is a commodity used by numerous kinds of artificers; as joiners, cabinet-makers, case-makers, hatters, book-binders, &c. and the consumption thereof is very considerable. The best is that made in England, in square pieces of a ruddy brown colour: Flanders glue, which is whitish and transparent, is held the next after the English. The most ordinary glue of France is black and opaque.

Glue is made of the skins of all kinds of beasts; as oxen, cows, calves, sheep, &c. The older the beast is, the better is the glue that is made of its hide. Indeed, it is rare they use whole skins for this purpose; those being capable of being applied to better purpose: but they make use of the shavings, parings, or scraps of the hides, and also horns; and sometimes they make it of the feet, sinews, nerves, &c. of beasts; and also of the pelts obtained from furriers.

That made of whole skins is the best, and that of sinews, &c. the worst: and hence, chiefly, arises the difference of glues, and the advantage of English and Flemish glues.

GLUE, *method of making*.—Mr. Clennell, in the Monthly Magazine for 1802, gives the following statement of the general mode of its manufacture. The materials above enumerated are "first digested in lime-water, to cleanse them from grease or dirt; they are then steeped in clean water with frequent stirring, and afterwards laid in a heap and the water pressed out. They are then boiled in a large brass cauldron with clean water, scumming off the dirt as it rises, and it is further cleansed by putting in, after the whole is dissolved, a little melted alum or lime finely powdered. The scumming is continued for some time, after which the mass is strained through baskets, and suffered to settle, that the remaining impurities may subside. It is then poured gradually into the kettle again, and further evaporated by boiling and scumming, till it becomes of a clear dark brownish colour. When it is thought to be strong enough, it is poured into frames or moulds about six feet long, one broad, and two deep, where it gradually hardens as it cools, and is cut out when cold by a spade into square cakes. Each of these is placed in a sort of wooden box open in three divisions to the back; in this the glue, while yet soft, is cut into three slices, by an instrument like a bow, with a brass wire for its string. The slices are then taken out into the open air, and dried on a kind of coarse net-work, fastened in moveable sheds four feet square, which are placed in rows in the glue maker's field. When perfectly dry and hard it is fit for sale. That is thought to be the best glue which swells considerably without melting by three or four days' immersion in cold water, and recovers its former dimensions and properties by drying. Glue that has got frost, or that looks thick and black, should be melted over again. To know good from bad glue, the purchaser should hold it between his eye and the light, and if it appears of a strong dark colour, and free from cloudy and black spots, the article is good." When glue is used by the carpenters, they break it and soak it for about 24 hours in cold water; and then melt the soaked pieces, causing it to simmer for a quarter of an hour over a slow fire and frequently stirring it. When cooled it becomes a firm gelly, which may be cut by any instrument. It is merely warmed for use, and in this state spread over the surface of the wood with a stiff brush. In an interval from one to three days the pieces of wood will be so perfectly cemented, that boards, thus cohering, will as readily break in any part as separate at the junction. Glued boards will not set in a freezing temperature; the stiffening being occasioned by the evaporation of the superfluous matter of the glue, which is prevented by a considerable degree of cold.

GLUE, *Bees*. See WAX.

GLUE, *Fish*, is a sort of glue made of the nervous and mucilaginous parts of a large fish, found chiefly in the Russian seas.

These parts, being boiled, bear a near resemblance to that viscid matter found on the skins of cod-fish When boiled to the consistence of a jelly, they spread it on a leaf of paper, and form it into cakes; in which state it is sent to us.

Fish-glue is of considerable use in medicine, and divers others arts; where it is better known under the name of isinglass and ichthyocolla. See ISINGLASS.

A strong and fine glue may be prepared with isinglass and spirit of wine thus: steep the isinglass for twenty-four hours in spirit of wine or common brandy. When the menstruum has opened and mollified the isinglass, they must be gently boiled together, and kept stirring till they appear well mixed, and till a drop thereof, suffered to cool, presently turns to a strong jelly. Then strain it, while hot, through a clean linen cloth, into a vessel to be kept close stopped. A gentle heat suffices to dissolve this glue into a transparent and almost colourless fluid, but very strong; so that pieces of wood, glued together with it, will separate elsewhere than in the parts joined. Boyle's Works abridg. vol. i. p. 130.

A strong compound glue may be made by infusing a mixture of common glue, in small pieces, with isinglass glue, in as much spirit of wine as will cover them, for about twenty-four hours: then melt the whole together, and add as much powdered chalk as will make it an opaque white.

A strong glue, that will resist moisture, may be obtained by dissolving gum sandarac and mastic, of each two ounces, in a pint of spirit of wine, and adding about an ounce of clear turpentine: then take equal parts of isinglass and parchment glue, and having pounded them into small pieces, pour the solution of the gums upon them, and melt the mixture in a covered vessel, with a heat less than that of boiling water: then strain the glue through a coarse linen cloth, and putting it again over the fire, add about an ounce of powdered glass.

Or, a strong glue, that will resist water, may be made by adding half a pound of common isinglass glue to two quarts of skimmed milk, and evaporating the mixture to a due consistence.

A glue, that will hold against fire and water, may be made by mixing a handful of quick-lime with four ounces of linseed oil, boiling them to a good thickness, and spreading the mixture on tin plates in the shade: it will thus become exceeding hard, but will easily be dissolved over a fire, and be fit for use. See CEMENT.

Gold

GOLD. *Gold*, Germ.; *Guld*, Swed. Dan.; *Or*, Fr.; *Arany*, Hung.; *Soloto*, Ruff.

Mineralogical Defcription.—This metal never having been found in a mineralized ftate, we are acquainted with one fpecies only, namely,

Native gold, which is fubdivided by Werner into three fub-fpecies, *viz. gold-yellow*, *brafs-yellow*, and *greyifh-yellow gold.* Though this fubdivifion may appear arbitrary, and not founded on conftant characters exclufively belonging to each of the above varieties or fub-fpecies, it is neverthelefs entitled to attention, fince colour, however unimportant it may be in the claffification of earthy foffils, conftitutes a character of confiderable value in native metallic fubftances, the range of whofe colours is confined to a narrow compafs. But alfo their geognoftic relation appears to conftitute a diftinction, at leaft between the two firft of the Wernerian fub-fpecies; for as to the third, or the *greyifh-yellow gold*, its claims to be kept feparate from the two others appear doubtful: all we know of it is its being found in fmall flat particles, along with that mixture of different metals called platina in grains, of whofe colour it partakes in general, and with which it is fuppofed to have occurred alfo originally under the fame geognoftic relations.

1. *Light or Brafs-coloured native Gold.* Meffing-gelbes gediegen gold of Werner. Its colour is pretty well indicated by its name; but it varies in intenfity from what may be called pale-gold yellow to yellowifh-filver white. It is alfo fometimes found with deep-yellow, and with pavonine tarnifh.

It occurs maffive, differninated in angular and amorphous particles, but more frequently in films, membranes, and plates even and curled or twifted, and with fmooth or drufed furface; alfo capillary, tooth and wire-fhaped, fhrub and fern-like, and as moniliform ftrings; often imitating reticulated and filigree work; all which forms are generally produced by the aggregation of minute imperfect cryftals. Among thefe, perfect cryftals are not unfrequently feen, fometimes fingle, oftener in groups, on the margin of the plates, &c. The following fecondary forms have been obferved: the cube; the octahedron; the garnet-dodecahedron; the leucite-dodecahedron with trapezoidal planes. Alfo modifications intermediate between the cube and the octahedron occur, but they

are ſcarce. The minute three-ſided pyramids, which are often ſeen to druſe the membrane, and the ſimple triangular marks on the plates of the Tranſylvanian native gold, are the reſults of hurried and diſturbed cryſtallization; the former of them being the ſolid angles of the cubical, and the latter the rudiments of the octahedral variety.

The cryſtals are minute (thoſe deſcribed by Mr. Eſmark as octohedra and cubes of two lines in diameter, have never before been heard of); their ſurface is always ſmooth.

Luſtre metallic: externally ſplendent: while that of the grains is ſometimes gliſtening, ſometimes approaching to dull; internally it is glimmering and gliſtening.

The fracture of gold is fine hackly. Its fragments are indeterminately angular.

It is ſoft, highly flexible, malleable, and ductile.

The ſpecific gravity of pure gold is from 19.253 to 19.640; but that of the braſs-yellow variety, owing to a greater proportion of ſilver with which it is alloyed, is generally conſiderably leſs, though always above twelve.

The light, or braſs-yellow gold, occurs almoſt always in veins in greywacke, greywacke ſlate, and newer porphyry; ſeldom, as the following ſub-ſpecies, in primitive rocks, or under other circumſtances that beſpeak a ſimilar remote antiquity.

It occurs chiefly with quartz and iron pyrites, and not unfrequently with grey antimony. Other concomitant ſubſtances are, among the earthy foſſils, calcareous ſpar, brown ſpar, barytes, ſelenite, and ſeldom ſmall quantities of bole, lithomarge, and common garnet; of metallic ſubſtances, red and vitreous ſilver ores, (ſeldom native ſilver,) copper pyrites, grey copper ore, copper green, brown iron ſtone, galena, green lead ore, blende, with occaſional traces of white cobalt, copper nickel, red orpiment, native arſenic, and arſenical pyrites.

2. *Deep or Gold-yellow Native Gold.*—Gold-gelbes gediegen-gold of Werner.

Its colour is the higheſt gold-colour, ſeldom verging on braſs yellow.

It occurs maſſive and in ſmall roundiſh and flattened pieces, as alſo in grains of various dimenſions, detached or diſſeminated; ſeldom in particular external forms, ſuch as in leaves and laminæ, filiform and moſslike; ſcarcely ever cryſtallized: almoſt all the cryſtalline forms deſcribed by authors belonging to the light-coloured ſub-ſpecies.

External luſtre gliſtening, ſometimes (as in the variety called Spaniſh ſnuff) diveſted of all luſtre. Its ſpecific gravity is rather greater than that of the light or braſs-coloured gold, with which it agrees in the remaining characters.

It occurs moſtly looſe, in alluvial ſituations, and in the ſand of rivers, and, as ſuch, appears to have been originally diſſeminated in rocks of ancient formation: it is, however, alſo found in veins in Norway, Siberia, Bohemia, Hungary, in the Eaſt Indies, &c. almoſt always diſſeminated in quartz, accompanied by iron-pyrites; but nothing is as yet known reſpecting the age of theſe veins. At Fatzebay it is found in minutely moſslike external forms, often of a dull powdery appearance, on common quartz ſometimes mixed with iron pyrites; in this ſtate it is by the miner called Spaniſh ſnuff.

Geographical ſituation.—The following localities comprehend both the ſub-ſpecies into which native gold is divided by Werner. By far the greater part of that found in Europe belongs to the braſs-yellow ſub-ſpecies, except the gold of rivers and alluvial ſoil, which is principally deep yellow, and to which the immenſe quantities of this precious metal, furniſhed by the other parts of the world, appear likewiſe to be referable.

Europe:—Hungary, the Bannat, and principally Tranſylvania. In Upper Hungary it occurs in gneiſs: at Schemnitz, in Lower Hungary, it is found accompanied with ſeveral ſilver ores, and with galena; at Kremnitz, in and on cellular and ſhattered quartz, lamellar barytes, with vitreous ſilver and grey copper ore, copper pyrites, brown ſpar, &c.; at Oravizza, in the Bannat, it occurs filiform and diſſeminated in pale fleſh-red and greeniſh-white limeſtone, with white cobalt ore and copper nickel. In Tranſylvania, the richeſt country of Europe in this metal, it principally occurs in a kind of clay-porphyry of different degrees of freſhneſs, which is the Saxum metalliferum of Born, in grauwacke and grauwacke ſlate: at Kapnik it is ſometimes found with red orpiment: at Staniſha in calcareous ſpar, mixed with arſenical pyrites, &c.: other places of Tranſylvania abounding in gold (which is for the greater part braſs-yellow), are Vereſhpatak, Abrudbanya, Boiza, Offenbanya, Fatzebay, Toplitza, Treſhtyan, &c. Alſo the rivers, both of Hungary and Tranſylvania, are richly auriferous; gold ſand is found in the Nera, and underneath a ſtratum of chalk on the plain traverſed by this river. The richeſt river of Tranſylvania is the Araniosh, and the plain bordering on the river Moroſh, contains likewiſe gold in grains, between a ſtratum of mould, and another of ſchiſtus, neither of which ſtrata is in the leaſt auriferous. Alſo at Olapian, gold is obtained by waſhing; it is there mixed with magnetic iron ſtone, titanium, garnet, and cyanite. The gold of the great rivers of Tranſylvania is generally of 21 carats, that of Olapian and Roſhinar is even of 23 carats, ſix grains.

In Germany it is found in ſeveral places, at Johangeorgenſtadt in Saxony, in Carinthia, where it accompanies copper-ores, in Tyrol and Saltzburg; but it is only in the laſt of theſe diſtricts, or rather in the chain of mountains, ſeparating Tyrol from Carinthia, that gold-mines are worked: in the Zillerthal it is found in various external forms, and accompanied with iron-pyrites, &c. in mica ſlate. In Bohemia gold occurs in quartz.

Spain is probably very rich in gold; certain it is that conſiderable gold mines were worked there in former times, and, according to Diodorus Siculus, as far back as the time of the Phœnicians, after whom the Romans undertook to work them; and Pliny informs us, that thoſe nations derived great profit from them. Aſturia was the province which furniſhed moſt of this metal. After the diſcovery of America theſe mines were entirely given up and loſt. The Tagus and ſome other rivers of Spain are likewiſe auriferous.

France has no gold mine that is worthy to be worked; the firſt diſcovery of gold in that country was made in 1781, at la Gardette, in the valley of Oyſans, in the preſent department of the Iſere: the mine was worked for ſix years, but the produce in gold and accompanying minerals was too ſmall to compenſate for the expence of obtaining them, and, indeed, the loſs amounted to upwards of 21,000 livres. It occurs there, with rock cryſtals and iron pyrites, in gneiſs. The ſand of ſeveral rivers of France is auriferous, ſuch as that of the Arrieze near Mirepoix, the Gardon and Ceze in the Cévennes, the Rhone in the Pays de Gex, the Rhine between Straſburg and Philipſburg, the Salat in the neighbourhood of St Giron, in the Pyrenees, the Garonne near Toulouſe, and the Hérault at Montpellier. Alſo moſt of the black ſand and of the bog-iron found in the neighbourhood of Paris is ſaid to contain a ſmall quantity of gold.

In Piedmont veins of auriferous pyrites and quartz are found near Macugnaga, at the foot of Monte Roſa: which mountain conſiſts of veined granite in horizontal beds. The veins of pyrites and quartz have upon the whole a perpendicular direction, but in ſome parts they croſs each other,

and where this takes place, *gruppi*, or nests, are found which contain the greatest proportion of gold. The proprietor of these mines extracted out of such nests, in no more than twenty-two days, 189 marcs of pure gold, although a hundred weight of the ore yields no more than from 10 to 12 grains of that metal. Formerly upwards of a thousand workmen were employed in these gold-mines; and the proprietors still possess 86 mills, by which from 10 to 12 pounds (of 12 ounces) of mercury impregnated with gold are produced per day. Twelve pounds of mercury contain two marcs of gold. There are likewise several auriterous rivers on the S. side of the Apenaine Alps, between mount Rosa and the valley of Aosta, such as the Avanson, which runs from the valley of Challant into the Doire, and where some gold-mines were also worked by the Romans; the Orco, &c.

Sweden has a gold mine at Edelfors in Smoland: the gangue, a brownish quartz, is said to be in a kind of hornblende slate, which also contains the metal disseminated.

Gold has also been found in Great Britain: in Cornwall; at Lead-hills, in Scotland, disseminated in quartz; at Wicklow, in Ireland, under the soil, and in a stream which runs over rocks of clay-slate with veins of quartz. It belongs to the deep yellow variety.

Asia—The gold-ores of Siberia are partly of the light coloured, but principally of the deep coloured variety: that of Berezof, which occurs in pyrites, or rather brown iron stone, and iron shot quartz, and in the rock which serves as gangue to the red lead ore, belongs to the latter. Patrin mentions a specimen of gold in spangles on hornsilver, found in one of the silver mines of Schlangenberg.

The geognostic relation of the gold found in several parts of India, in Japan, the Philippine and Maldive islands, Sumatra, Borneo, &c. is not known; all the specimens from India, that have come under our inspection, were in the form of small rounded and amorphous particles in quartz, and belonged to the deep yellow variety.

Africa.—Of the occurrence of gold in this part of the world we know so much, that the greatest part, at least of that which comes to Europe, is deep yellow and in grains. African travellers have made us acquainted with a few of its localities, but not with any particulars relating to its geognostic habitudes. Though the commerce of gold-powder extends almost over the whole of Africa, yet, according to Heeren, there is none to be found in its northern parts. Among the principal African gold mines are those of Kordofan, between Darfur and Abyssinia, mentioned by Browne. The ancients, says Brongniart, appear to have been acquainted with these mines: they considered Ethiophia as a country rich in gold; and we find in Herodotus, that the king of that country exhibited to the ambassadors of Cambyses all the prisoners of war fettered with chains of gold.

A second most considerable district for gathering gold-powder appears to be southward of the great desart of Zahara, in the west of Africa, at the foot of those lofty ridges of mountains on which originate, among many smaller rivers, the Senegal, the Gambier, and Niger. The country of Bambouk, at the N.E. of these mountains, is, according to Golberry, that which furnishes the greatest quantity of gold which is sold on the west coast of Africa, from the mouth of the Senegal to the Cape Palmas. This gold is found in spangles and small lumps, principally near the surface of the earth, in the beds of rivulets, and always in a ferruginous soil. In some parts of the country the negroes sink something like shafts, but without giving any support to the sides of the pit; nor are they wont to follow up the vein, if any should appear, or to make galleries. The metal is obtained by repeated washing of the earth that includes it. The same country furnishes likewise the greatest part of the gold carried to Morocco, Fez, and Algiers, by the caravans which, from Tombuctoo, travel through the great desart of Zahara. The gold which is brought to Cairo and Alexandria from Senaar comes likewise from these. See Parke's travels, where also an interesting account is to be found of the gold in Manding, and of the process by which the negroes obtain it.

The third principal district of Africa, for collecting gold, is on the S.W. coast between 15° and 22° S. lat. opposite Madagascar. This gold comes principally from the country of Sofala. According to the relation of some travellers in this part of the world, the gold is found there not only in powder, but likewise in veins. Some are of opinion that the country of Ophir, from whence Solomon obtained gold, was situated on this coast.

America.—The gold of this part of the world, as far as we are acquainted with it, is so equally the production of the sand of rivers and of alluvial land; but it is also, though rarely, found in veins. South America, particularly Brasil, Choco, and Chili, are the countries that yield most; but some is also found in North America, particularly in Mexico, where it occurs along with silver-ores. The annual produce of these Mexican mines is valued at from 12 to 1500 kilograms All the rivers of the Caraccas, 10° north lat. are auriferous.

The gold of Chili, according to Frezier, is lodged in the alluvial formation.

The Peruvian gold occurs in ferruginous quartz; that of Choco, the richest province in gold in South America, is found as grains in alluvial country, and in rocks belonging to the newest fletz-trap formation. Almost all we know respecting the geognostic situation of the gold of Spanish America, we owe to M. de Humboldt.

Brasil furnishes gold in abundance, and it is from thence that the greatest part actually seen in commerce is brought to Europe. There are, however, properly speaking, no gold-mines in that country; the gold is not found there in veins, but disseminated in sand and other alluvial depositions, out of which it is obtained in the usual manner.

The gold that has been furnished by Brasil within 120 years, may be valued (according to Correa) at 2,400,000,000 of French livres; and, according to other authors, the amount is calculated to be 24,000,000 per annum. Brongniart. See ORES.

Observations—1. It would appear that most writers who adopt Werner's distinction between gold-yellow and brass-yellow gold, have mistakenly described the one sub-species for the other, and some even speak of "grey-yellow gold from Transylvania." The sub-division alluded to may be deemed inadmissible; but if it be at all adopted, by far the greater part of the native gold of Transylvania and Hungary, and consequently almost all crystallized gold, must necessarily be referred to the light-coloured, and that found in the sand of rivers to the deep-coloured sub-species; and this not on account of their colour only, usually indicative of differences in the chemical composition of metals, but principally on account of the geognostic relations under which they respectively occur, and on which great stress appears to be laid by Werner.

2. Iron pyrites, containing not unfrequently a considerable portion of gold, in most cases invisibly dispersed and disguised, has by some been considered as a species of gold ore; a distinction to which (though such auriferous pyrites are often subjected to metallurgical treatment for extracting that metal, as will be seen hereafter) it cannot be considered as entitled. See PYRITES, *Auriferous*.

The brown cubic cryſtals from Bereſof, in Siberia, which contain grains of gold, are conſidered by ſome as decompoſed, by others as hepatic pyrites, and by ſome as brown iron ſtone in ſuppoſititious cryſtals. Whatever they may be, they are certainly not what Werner means by hepatic pyrites.

3. The native gold of Tranſylvania is often accompanied, and ſometimes incruſted, by particles of a pale yellow earthy ſubſtance, which was conſidered by Hacquet as an oxyd of gold. Muller and others have deſcribed it as iron-ochre, from which, however, it appears to differ both in colour and conſiſtence. It is almoſt always to be met with in the ſpecimens of native gold from Vereſhpatak, but ſometimes in ſuch fine particles as to appear merely as a tarniſh on the metal. It is to this duſt probably that the gold ore, called Spaniſh ſnuff, owes its mat, yellowiſh-brown colour. It deſerves further examination.

4. The grey metallic ſubſtance occurring as acicular indeterminate cryſtals, along with the gold of Siberia, in quartz, and which has been deſcribed as tellurium, as grey copper ore, &c. appears to be native biſmuth.

For the *chemical characters* of gold, and the *uſes* to which it is applied, ſee the ſequel of this article.

Extraction of Gold.—This metal is obtained ſeparate from foreign ſubſtances, with which it is mixed by amalgamation with quickſilver. After it has been freed, by pounding and waſhing, from the ſtony matter, it is triturated with about ten times its weight of mercury. The more fluid part of the amalgam is forced through leather, while that which is more conſiſtent, and which contains the chief part of the gold, remains. This is ſubjected to diſtillation, the quickſilver is ſeparated and evaporated, and the gold remains in a ſtate of fuſion. When this metal is found in other ores, they are firſt roaſted, to diſperſe the volatile principles, and to oxidize the other metals. The gold, which is but little ſubject to oxydation, is extracted by amalgamation, by cupellation, or other methods adapted to each ore, according to its properties or conſtituent parts. The metal obtained in theſe ways is always more or leſs alloyed, particularly with ſilver and copper. The firſt ſtep in its purification is the proceſs of *Cupellation*, to which article in our Cyclopædia the reader is referred for accurate information on this part of the ſubject.

The gold, after it has been ſubmitted to this proceſs, is often alloyed with ſilver, which, being nearly as difficult of oxydation, is not removed by the action of lead, and hence the neceſſity of the operations denominated *Parting* and *Quartation*, which may be explained in a few words.

In *Parting*, the metal is rolled out very thin, and cut into ſmall pieces, which are digeſted in diluted nitric acid moderately hot. The acid has an action upon, and diſſolves the ſilver, leaving the gold undiſſolved in a porous maſs. When, however, the proportion of ſilver is very ſmall in compariſon of the gold, the latter ſometimes protects the former from the action of the acid; in ſuch caſes the previous ſtep of *Quartation* is employed, which is ſo named on account of the proportion of materials employed, *viz.* three parts of ſilver, with one of gold, and then ſubjecting the alloy, rolled out, to the operation of the acid. Sometimes they are melted together, and ſulphur thrown in, the ſulphur combines with the ſilver, and the gold falls to the bottom. It is obſerved by Lagrange, that rolling and annealing are operations very neceſſary to the ſucceſs of the parting proceſs, and which require ſome precautions. 1ſt. The plate muſt not be too thin, leſt it ſhould break in conſequence of the motion communicated to it by the action of the acid; if it is too thick the acid could not penetrate to its centre. 2dly. The annealing of the plate, at the ſame time that it gives pliability, facilitates its being rolled without cracking; it alſo opens the pores of the metal, which the rolling may have preſſed together, and by theſe means favours the action of the acid.

The proceſs recommended by Bergman is this: firſt to diſſolve it in nitro-muriatic acid; the ſilver is depoſited ſpontaneouſly in the form of muriate of ſilver, which is inſoluble; the gold is precipitated in fine powder by the ſulphate of iron. Each of the above-mentioned proceſſes is performed in ſuch a manner as to lead to an eſtimate of the quantity of gold, and alſo of the different metals with which it is alloyed.

Gold, it is ſaid, by ſome able French chemiſts, as Le Sage and Rouelle, exiſts in the vegetable kingdom, it having, in experiments inſtituted for the purpoſe, been extracted from the aſhes of certain plants; the quantity, however, being, of courſe, too trifling to be ſought after for practical purpoſes, it is ſufficient merely to mention the fact in this place.

Gold, *Chemical Properties of*.—Gold melts at the temperature of 32° of the ſcale of Wedgewood; and what is very remarkable is, that it is more difficult of fuſion in the ſtate of filings and grains, than in larger maſſes; and that the ſmall fragments, even after they are fuſed, remain in ſeparate globules: and in order to make them run into one maſs, a little nitre or borax is thrown into the crucible. Gold, which has only been ſubjected to a degree of heat barely neceſſary for its fuſion, is brittle after cooling. To preſerve its ductility, which, as will be ſeen farther on, is one of the more important mechanical properties of gold, the temperature muſt be raiſed much higher. It is brittle alſo when it is too ſuddenly cooled after fuſion. By an increaſe of temperature while the gold is in fuſion, it becomes convex on the ſurface, and when it cools, it ſinks, circumſtances which are aſcribed to the expanſion and contraction of the metal. When it is gradually and ſlowly cooled, it cryſtallizes in the form of quadrangular pyramids, or regular octahedrons. If the heat be continued while it is in perfect fuſion, it ſeems to undergo a kind of ebullition. This circumſtance was noticed by Homberg and Macquer, as well in the application of the burning-glaſs, as when a ſmall globule of the metal was acted on by the blow-pipe. Macquer aſſerts that it roſe in vapour to the height of five or ſix inches, and attached itſelf to the ſurface of a ſilver plate, which it completely gilded.

The ſtrongeſt heat of a furnace, which has been applied to gold in fuſion, has been found incapable of producing the ſmalleſt change or the leaſt tendency to oxydation; but, by the action of a very powerful burning-glaſs invented by Tſchirnhauſen, and which has been deſcribed under the article Burning-glass, Homberg found that gold, placed in its focus, not only roſe in vapour, but that it was covered with a violet-coloured vitreous oxyd. The experiment was frequently repeated, ſo as to aſcertain the fact moſt completely. The ſame thing has been done by means of the electric diſcharge, by which gold-leaf, placed between two cards, has been converted into a violet-coloured powder. Theſe inſtances of real oxydation were, at firſt, regarded, by ſome who witneſſed the experiments, as merely minute mechanical diviſions of the metal, but this apparent objection has been removed by the experiments of Van Marum on the combuſtibility of gold by means of the large electrical machine at Haerlem. A ſtrong electrical ſhock was paſſed through a golden wire ſuſpended in the air. It kindled, burned with a perceptible green flame, and was reduced to fine powder, which was diſſipated in the air. A ſimilar oxydation has been obſerved to take place on the gilding in the inſide of

houses, or on the furniture which has been struck with lightning. The purple oxyd of gold, thus obtained, contains five or six *per cent.* of oxygen. By precipitation from some of its saline combinations, a yellow oxyd has been obtained, in which the proportion of oxygen amounts to ten *per cent.* The oxyd in both instances may be decomposed, and the oxygen completely expelled, by an elevation of temperature not much superior to that of ignition.

The attraction of gold to oxygen is so weak, that it is scarcely affected by the greater number of acids. It was formerly supposed to be perfectly insoluble in the nitrous and nitric acids, which in general part with oxygen with so much facility, and when gold leaf is put into the acid cold, it seems to suffer no change, but when nitric or nitrous acid is boiled on gold, it is capable of dissolving a small portion of it. The quantity dissolved is, however, so inconsiderable, and depends on so many conditions, which it is needless to enumerate, that the accuracy of the processes of assaying can scarcely be affected by it.

When gold is dissolved in the nitro-muriatic acid, or in a mixture of equal parts of nitric and muriatic acids, an effervescence takes place, and the solution becomes of a yellow colour. In this process the nitric acid is decomposed, its oxygen combines with the gold, and the oxyd, as it is formed, is dissolved in the muriatic acid. By adding lime-water a precipitate is formed, which is the yellow oxyd of gold; consisting of from eight to ten parts of oxygen in the hundred. There is no action between gold and azote, hydrogen, carbon, or sulphur: but the oxyds of gold are readily decomposed by hydrogen, as will be soon seen.

Phosphorus combines with gold by heating together in a crucible a mixture of one part of gold in filings, with two parts of phosphoric glass, and an eighth part of charcoal. Great part of the phosphorus is separated from the acid, and driven off, but there remains a small quantity united with the gold, forming a phosphuret of gold. It may be done also by adding phosphorus to gold in a red heat in a crucible. It is, in this state, pale coloured, granulated, brittle, and a little more fusible. The proportion of phosphorus is not more than one part in twenty-four; and the substance may be decomposed by being kept in fusion; the phosphorus is driven off in the state of vapour, and inflamed. Bergman has arranged the affinities of gold and its oxyds in the following order:

Gold.	*Oxyds of Gold.*
Mercury,	Muriatic-acid,
Copper,	Nitric,
Silver,	Sulphuric,
Lead,	Arsenic,
Bismuth,	Fluoric,
Tin,	Tartaric,
Antimony,	Phosphoric,
Iron,	Prussic.
Platina,	
Zinc,	
Nickel,	
Arsenic,	
Cobalt,	
Manganese.	

Salts of Gold.—These are the nitrate and muriate.

1. *Nitrate of Gold.* When concentrated nitric acid is several times successively poured upon gold, boiled and distilled to dryness, the gold is dissolved, and the solution assumes a yellowish colour. This solution is more readily effected in proportion to the quantity of gas or nitrous gas which the acid contains. Gold-leaf, according to Fourcroy, is dissolved in nitric acid, impregnated with nitrous oxyd, and he supposes that it is owing to the nitrous oxyd that the gold is oxydated, this oxyd being so much more easily decomposed than the nitric acid. The acid which, at first, is deprived of its colour by the oxydation of the gold, as this oxyd is dissolved, assumes an orange-yellow colour, holding in solution the nitrate of gold with an excess of acid. The nitrate cannot be obtained in crystals, and it is decomposed by heat or by being exposed to the light of the sun; it is also decomposed by the alkalies, or by introducing a plate of tin or silver into the solution, and the purple oxyd is precipitated in the form of powder; and likewise by muriatic acid, which at the instant of combination converts the orange-colour to a pure yellow.

2. *Muriate of Gold*—Muriatic acid of itself has no action on gold, or on its purple oxyd, but gold is immediately oxydated and then dissolved in oxymuriatic acid: or if nitric acid be added to the muriatic in certain proportions, the solution of gold in the mixture is readily effected: hence the nitro-muriatic acid was distinguished by the name of "aqua regia," because it dissolved gold, which was regarded by the alchemists as the king of metals. The nature of the chemical action is thus explained. Gold is oxydated with great difficulty, but it is effected by oxymuriatic acid, which readily parts with its oxygen, or by the addition of the nitrous to the muriatic, the former of which is decomposed, giving out its oxygen to the gold, which being now oxydated is dissolved in the muriatic acid, forming with it a muriate of gold. This solution of the muriate of gold is of a deep yellow colour, extremely acrid and caustic; has an astringent metallic taste, and stains the skin of a deep purple colour, which becomes darker by exposure to the air and light. It produces a similar effect on all vegetable and animal matters, and on marble and siliceous stones. By evaporating the solution to one half, nitric acid is disengaged, and crystals are obtained. These assume a red colour by the action of strong light. They attract moisture from the air, and spontaneously become liquid. When oxymuriatic acid is used, the oxygen of this acid being retained even by a weaker affinity than the nitric acid, the gold attracts it, and combines with the muriatic acid. In this case the solution is slow, and but a very small quantity of gold can be dissolved, partly from the oxymuriatic acid not being in a very concentrated state, and partly, it is supposed, from the quantity of oxygen present not being such as to form a sufficient quantity of oxyd to saturate the acid. It ought, however, to be observed, that if the late discoveries of professor Davy be established, which make the oxy-muriatic acid a simple substance, and even possessing no oxygen whatever, then a new theory must be introduced to account for the facts above-stated. In oxy-muriatic gas, gold-leaf is instantly fused with inflammation, and dissolved.

Gold cannot be dissolved by the other acids when in its metallic state, but its oxyds may be combined with them, and a number of the salts of gold be formed. The sulphate and nitrate also, as we have seen, do not crystallize: the phosphate of gold may be fused, and in this state it forms a fine red glass. We shall now briefly notice some of the properties of the muriate of gold. In connection with this subject, we must not omit the experiments of Mrs. Fulhame, which she announced in an "Essay on Combustion," with a view to a new art of dyeing and painting, &c. in the year 1794, and which were, at that period, expected to lead to some important practical results.

The muriate of gold is very soluble in water, and is decomposed in hydrogen gas. If a piece of silk be moistened

with a ſolution of muriate of gold, the ſalt is decompoſed, and the gold, reduced to the metallic ſtate, attaches itſelf to the ſilk. It is decompoſed alſo by phoſphorus. If a ſtick of phoſphorus be introduced into a ſaturated ſolution of muriate of gold, the ſalt is decompoſed, and the gold, being reduced to the metallic ſtate, forms a cylindrical covering to the phoſphorus, which may be ſeparated by diſſolving the latter in hot water. A ſimilar effect is produced by burning ſulphur, by ſulphurated and phoſphorated hydrogen gaſes, and by ſulphurous acid. If a ſolution of muriate of gold be cautiouſly added to ſulphurous acid, a fine pellicle of gold appears on the ſurface, which is inſtantly precipitated in the form of ſmall grains. Theſe, and many other experiments equally curious and intereſting, were firſt deſcribed by the lady above-mentioned, and the rationale of the ſubject is thus explained. All the ſubſtances which have been enumerated have a ſtronger affinity for oxygen than gold, ſo that the oxyd of gold, in combination with the acid, is decompoſed; the oxygen combining with the hydrogen, and forming water, or with the phoſphorus or ſulphur, and forming ſulphuric or phoſphoric acid.

The muriate of gold is ſoluble in ether, and forms with it a ſolution of a golden yellow colour, which floats on the top of the fluid. By the addition of ether to a ſolution of gold, and agitating the mixture, as ſoon as it is left at reſt, the two liquids ſeparate, the ether riſes to the top, and aſſumes a yellow colour, while the nitro-muriatic acid remains below and becomes white. By a proceſs of this kind a tincture of gold was prepared, called "potable gold." The ſolution of gold in ether is not permanent: it is quickly reduced to the metallic ſtate, and is ſometimes found cryſtallized on the ſurface. The etherial ſolution is uſed by Mr. Stodart for defending lancets, and other ſurgical inſtruments, from injury by a moiſt atmoſphere.

The muriate of gold is decompoſed by all the alkalies and earths, and is reduced to the ſtate of yellow oxyd.

Moſt of the metals decompoſe the muriate of gold: copper, iron, zinc throw down the gold in its metallic ſtate: other metals, as ſilver or lead, in the ſtate of purple oxyd. The precipitate obtained by means of tin is valued for the beauty of the colour which it gives to glaſs or enamel. This preparation is known to artiſts by the name of the "Purple powder of Caſſius," and it may be obtained by various proceſſes. That which is commonly reſorted to, is to diſſolve pure gold in a nitro-muriatic acid, which is compoſed of three parts of nitric and one of muriatic acid. A ſolution of tin is to be prepared by diſſolving the metal, in ſmall portions at a time, in an acid containing two parts of nitric and one of muriatic acid, previouſly diluted with an equal weight of water. This ſolution, after it is ſaturated, is largely diluted, perhaps with a hundred parts of diſtilled water: to this the ſolution of gold equal in quantity to half the quantity of ſolution of tin, is added, and the precipitate is obtained after it is allowed to ſubſide, which is to be waſhed and dried. This is the only known preparation capable of giving a red colour to glaſs; and if the experiment be performed with accuracy and judgment, the glaſs ſo treated ſerves as a capital imitation of the ruby. The proceſs is, however, attended with conſiderable difficulty, owing to the colour of the precipitate being various, from circumſtances not eaſily diſcovered. According to Pelletier, it is a compound of oxyds of tin and gold; and its formation is owing to the ſtrong attraction of the tin for the oxygen, with which it is diſpoſed to combine in large quantities. When the ſolutions, above deſcribed, are mixed, the oxyd of tin, which is nearly at the minimum of oxydizement, attracts part of the oxygen of the oxyd of gold: the two oxyds thus brought to ſtates of oxydizement, different from thoſe in which they exiſted in the ſeparate ſolutions, and probably likewiſe exerting mutual affinities, are no longer ſoluble, and are precipitated in combination. Muriate of gold is decompoſed by ſome other metallic ſalts, in conſequence of ſimilar actions; the oxygen of the oxyd of gold being attracted by the oxyd of the other metal, which hence paſſes to a higher ſtate of oxydizement. Thoſe which have a ſtrong tendency to exiſt in ſuch a ſtate, are capable even of completely de-oxydizing the oxyd of gold. Example.—If a ſolution of the green ſulphate of iron be added to the ſolution of muriate of gold, the gold is precipitated in very minute particles in the metallic ſtate, while the iron paſſes to the ſtate of a red ſulphate. A ſolution of muriate of gold, when concentrated by evaporation, yields beautiful yellow cryſtals, not unlike topazes.

Gold, as we have ſeen, does not combine with ſulphur by fuſion, and on this is founded a method of freeing it from ſilver or other metals, the alloy being fuſed with ſulphur, the ſilver, &c. unite with the ſulphur, leaving the gold ſeparate. But gold and ſulphur may be united by the medium of an alkali. Example.—Let a ſulphuret of potaſh be fuſed with one-eighth of its weight of gold-leaf, and the combination is even ſoluble in water, the ſolution being of a green colour.

Alloys of Gold.—Gold forms alloys with the greater number of the metals, which produce on the metal ſo alloyed a very particular change in its properties. An extenſive and accurate ſeries of experiments on theſe alloys was made by Mr. Hatchet, with the view of determining ſome important and intereſting facts relating to the uſe of gold as a coin. Of theſe we ſhall give a brief abſtract, referring our readers for a more particular account to the Tranſactions of the Royal Society for the year 1803.

The chief enquiry of Mr. Hatchet, as connected with the alloys of gold, was, whether ſoft and ductile gold, or gold made as hard as is compatible with the proceſs of coining, ſuffers moſt by wear. His experiments were intended to examine the effects which various metals produce upon gold, when combined with it in given proportions, beginning with $\frac{1}{12}$th, which is the ſtandard proportion of alloy, and gradually decreaſing to $\frac{1}{1920}$ part of maſs. The reſults drawn from the trials were, that fine gold, alloyed with ſilver, with copper, and with tin, did not ſuffer any loſs during the experiment. The gold alloyed with lead only loſt three grains, chiefly by vitrification; with iron it loſt 12 grains, which formed ſcoria; with biſmuth it loſt 12 grains, chiefly by vitrification; with zinc it loſt a pennyweight by volatilization; and with arſenic, it not only loſt the whole quantity of alloy, but alſo two grains of the gold which were carried off in conſequence of the rapid volatilization of the arſenic. Hence it was inferred that only two metals are proper for the alloy of gold coin, namely, ſilver and copper; as all the others either conſiderably alter the colour, or diminiſh the ductility of gold. In reſpect to the latter quality, the different alloys employed in this ſeries of experiments appear to affect gold nearly in the following decreaſing order: 1. Biſmuth. 2. Lead. 3. Antimony. 4. Arſenic. 5. Zinc. 6. Cobalt. 7. Manganeſe. 8. Nickel. 9. Tin. 10. Iron. 11. Platina. 12. Copper, and, 13. Silver. The three firſt have nearly the ſame effect on gold, and biſmuth is found to render gold brittle when the proportion of that metal is to gold only as 1 to 1920; even the vapour ariſing from biſmuth, lead, and antimony in fuſion, produces theſe changes.

The alloy with platina is of a yellowish white colour, very ductile, and of a considerable specific gravity. The alloy with silver in the standard proportion, or 1 to 12, approaches, as we have seen above, the nearest to the ductility of fine gold of any alloy, and its specific gravity differs but little from the mean specific gravity of the two metals. When the silver amounts to ⅕th, the colour of the alloy approaches to green, and forms the green gold of the goldsmiths. In combination with copper, gold has its colour rather heightened than impaired; its hardness is increased and its ductility very little lessened, when the standard proportion of 1 part in 12 is not exceeded. This alloy of 22 carats fine is generally used, when gold is fabricated into plate or ornaments, and likewise forms the gold coin of the country. With quicksilver, gold unites with great facility, making with it an amalgam which will be described hereafter. The alloy with iron is much harder than gold, very ductile and malleable; but the colour is debased to a dullish grey, inclining to white. Tin was formerly regarded as the metal which rendered the alloy with gold the most brittle of all the alloys, but the experiments of Mr. Bingley and Mr. Hatchet have shewn that this notion is to a certain extent erroneous, and that the effects produced by the mixture of tin with gold, ought probably to be ascribed to other metals, with which the tin was contaminated, such as bismuth, antimony, lead, and zinc. The alloy, consisting of equal parts of zinc and gold, is very hard and susceptible of a fine polish, and not being subject to much alteration from the air, it is recommended for the fabrication of the mirrors of telescopes. The alloy of gold with silver, in which there is only $\frac{1}{20}$th part of silver, changes the colour of the gold very sensibly; and the alloy is employed for soldering gold, being more fusible than this metal.

Gold, *Physical properties of*. *Gold*, *aurum*, a yellow metal, heavy, pure, ductile, malleable, and shining; and on those accounts, the most valuable of all metals. In fusibility it ranks between silver and copper; it is not oxydable by fusion in atmospheric air; nor is it acted upon by any of the acids, except the oxymuriatic and nitro-muriatic.

The yellow colour of gold is rendered paler by fusion with borax; but this may be prevented or corrected by fusion with nitre, or sal ammoniac. The colour of gold is heightened by an alloy of copper, and this property of copper has given rise to sundry processes for exalting the colour of this noble metal. Other metals render it paler. The alchemists call gold, *sol*, the sun; to denote its pre-eminence over the other metals, which are called by the names of the planets. Its symbol, or character, is ☉; which, in their hieroglyphical way of writing, denotes perfection, simplicity, solidity, &c.

The weight of gold is to that of water, according to some statements, as 19.637 to 1000. Fine gold, immersed in water, weighs nearly one nineteenth part less than in air, and consequently it is upwards of nineteen times heavier than its own volume of water. However, the specific gravity of gold, or its comparative weight with an equal volume of water, has been variously assigned: some have made it 19.637, others 19.640, and in the Swedish Transactions it is made no less than 20.000; that of water being 1000. Others again have made it as low as 18.75. But from the experiments of Mr. Ellicot, it does not appear to have exceeded 19.207; and from those of Dr. Lewis, on the purest gold, well hammered, its gravity is stated between 19.300 and 19.400. In all experiments of this kind, the result should be specified with an account of the sensibility of the balance, and the quality and warmth of the water. An increase of heat rarefying water more than it does gold, the gold must turn out proportionably heavier than an equal volume of the expanded fluid; and this difference is more considerable than it has generally been supposed. From freezing to boiling water, or by an augmentation of heat equivalent to 180° of Fahrenheit's thermometer, Dr. Lewis found that a rod of gold was lengthened about one part in 700, and consequently its volume increased about one part in 233, while the volume of water is increased one twenty-sixth or more; hence it appears, that by an augmentation of 40° of the thermometer, or from a little above freezing to the summer heat, the volume of gold, if its expansion be uniform, is increased one part in 1048, and that of water one in 117; and the gravity of gold, weighed in the water so warmed and expanded, should be greater than when the gold and water are 40° colder, in the proportion of about 19.265 to 19.400: and this calculation gives a difference, in the gravity, of 0.034 for every 10° of the thermometer; but some trials seemed to make it greater. It has been imagined, that the comparative gravity of gold to brass weights, which are more than double in volume to an equal weight of gold, must be so far influenced by the variable gravity of the atmosphere, that there must be an advantage in buying gold by weight when the air is lightest. But Dr. Lewis observes, that this difference appears too inconsiderable to be regarded in a commercial view. For the loss of weight of the two metals in the air being as much less than their loss in water, as air is lighter than water; and air, if we admit the accuracy of the conclusion deduced from an experiment of Mr. Hawksbee, being in its lightest state about a 937th, and in its heaviest state about an 848th part of the weight of water; it will be found, on calculation, that the gold preponderates above the brass, in the heaviest more than in the lightest air, only by one part in 145.000, or one grain in about 302 ounces; which is a difference too minute to be sensible in the nicest balance. If the mean gravity of gold be reckoned 19.300, as a cubic inch of water weighs about 254 grains, a cubic inch of gold will consequently weigh about 4902 grains, or 10 ounces, 102 grains. The pound weight, or twelve ounces Troy, of gold, is divided into twenty-four carats. Dr. Lewis states the specific gravity of fine gold at 53° Fahrenheit, to be 19.376. According to Brisson the specific gravity of fine gold in ingot is 19.258, and when hammered 19.361. The specific gravity of gold made standard by British copper, was found by Mr. Hatchett (see Phil. Trans. for 1803) to be 17.281, when cast in an iron mould; but when the same was cast in sand, it was only 16.994. (See *Specific* Gravity.) The softness of gold, for it is nearly as soft as tin, and its toughness, adapt it for receiving the impressions of dies, and of course to be reduced to the state of coin, and for various other purposes in the arts. It is but slightly elastic and sonorous. With regard to tenacity, it is inferior to iron, copper, platina, and silver, and therefore the assertions of former chemists and philosophers have been contradicted by later experiments, for gold has been usually represented as the most tenacious as well as the most ductile of all metals. Its malleability and ductility are sufficiently evinced by the Gold-*leaf* and Gold-*wire*, which see. See also Ductility.

The value of gold to that of silver, was anciently only as twelve to one. Indeed, this proportion varies as gold is more or less plentiful: for Suetonius relates, that Cæsar brought such a quantity of gold from Italy, that the pound of gold was only worth seven pounds and a half of silver. In our coinage, the value of fine gold to fine silver is nearly as 15¼ to 1. (See Coin and Standard.) Sir Isaac Newton observes, in a representation to the lords of the treasury

in the year 1717, that in the mints of Spain and Portugal the value of gold is fixteen times that of filver; but that in thofe countries, payments in filver bearing generally a premium of fix per cent. the proportion may be confidered as fixed by commerce at $15\frac{1}{17}$ to 1; that in the other parts of Europe, the value of gold is at moft fifteen, and in China and Japan but nine or ten times that of filver; fo that gold is rated higher in England than in any other part of Europe, and higher in Europe than in the Eaftern countries. Hence, in great meafure, arife the profits of exchanging gold for filver in one place, and re-exchanging them in another; and hence the greater difparity between the relative quantities of gold and filver in one commercial nation than in another; this metal being brought in moft abundance which is rated higheft in proportion to the other, and that which is rated loweft being drained away. There are various ways of determining the finenefs of gold; or the proportion of alloy which it contains. Thofe who are ufed to this bufinefs can judge nearly the proportion of alloy from the colour of any given mafs, provided that the fpecies of alloy be known. For the method of doing this, fee Touch-*needles*. The great excefs of the weight of gold, above that of the metals ufed for its alloy, affords another method of determining the quantity of alloy in any given mafs, where the fpecies of alloy is known. Thus fine gold lofes in water one grain in every 19.3 nearly; and fine filver lofes one grain in about eleven; from whence it is eafy to find the lofs of any number of grains of each, and confequently of any affignable mixture of the two metals. Thus, fifty grains of gold will lofe above $2\frac{1}{2}$, and fifty grains of filver fomewhat more than $4\frac{1}{2}$; fo that a mixture of equal parts of the two will lofe above feven in a hundred, or one in fourteen. A mixture of gold with half its weight of filver will lofe one part in 15.4; with a third of filver, one in 16.2; with a fourth, one in 1.67; and with an eleventh of filver, which is the ftandard proportion of alloy, one in 18 1. On this principle, the fpecific gravity or proportional lofs in water, of gold alloyed with different quantities of filver, copper, and mixtures of both, may be computed and formed into tables for ufe. The accuracy of this method, it fhould be obferved, depends on the fuppofition that each of the two metals, that are melted together, retains its own proper gravity, which is the cafe in mixtures of gold and filver; but gold and copper, melted together, are fpecifically lighter than if they were weighed feparately; or the fpecific gravity of the alloy is lefs than that of the mean of its ingredients; the cafe is the fame with the alloys of nickel and gold, of lead and gold, of iron and gold; but the reverfe happens in mixtures of gold with zinc, bifmuth, and tin. It appears, therefore, that the hydroftatic balance cannot difcover, with certainty, the exact finenefs of gold, unlefs when filver is the metal mixed with it.

There are various methods of feparating gold from gilt works: it may be feparated from the furface of filver, either by fpreading over the gilt filver a pafte made of powdered fal ammoniac moiftened with aquafortis, and heating it till the matter fmokes, and is nearly dry; throw it into water, and the gold will eafily come off by rubbing it with a fcratch brufh: or, by putting the gilt filver into common aqua regia, nearly boiling, and turning the metal frequently, till it becomes all over black; then wafh it with water, and rub it with the fcratch brufh, which will difengage the gold left by the aqua regia. See Gilding.

Gold may be feparated from gilt copper, by applying a folution of borax to the gilt parts with a pencil, and fprinkling over the place thus moiftened a little powdered fulphur; when the piece is made red-hot and quenched in water, the gold may be wiped off with a brufh.

Gold may be recovered from wood, gilt on a water fize, by fteeping it for a quarter of an hour in a quantity of very hot water, fufficient to cover it; then fcrub the wood in a little warm water, with fhort ftiff briftle brufhes of different fizes: boil the whole mixture of water, fize, gold, &c. to drynefs; make the dry matter red-hot in a crucible to burn off the fize, and grind the remainder with mercury. The gold will be more eafily laid hold of by the mercury, by the addition of fome clean fand.

Gold, *Alchemical Hiftory of.* See Philosopher's *Stone*, and Transmutation.

Gold, *Amalgam of*, is a preparation of gold much ufed by the gilders (fee Gilding); and it is made by heating fome pure quickfilver in a clean crucible, and adding to it, when it is nearly boiling, about a fixth of its weight of fine gold in thin plates that are hot; after this mixture has been kept hot for a few minutes, it becomes an homogeneous fubftance; and when cold, it is put into a piece of foft leather, and which is gradually preffed till the fluid part of the amalgam, confifting almoft wholly of mercury, is forced through the pores of the leather; while the gold, combined with about twice its weight of mercury, will remain in the ftate of a yellow filvery mafs, of the confiftence of foft butter; when this mafs has been bruifed in a mortar, or fhaken in a phial, with repeated portions of falt and water, till the water receives no foulnefs from it, it is fit for ufe, and may be preferved for any time in a corked phial. For the purpofes of gilding it is of great importance, that this amalgam fhould be formed of pure materials, as any portion of lead or bifmuth would deteriorate the colour of the gold, and tarnifh it with black fpecks. The mercury fhould therefore be previoufly diftilled from the red precipitate (nitrous red oxyd of mercury), either alone or mixed with a little charcoal powder. See Amalgam and Mercury.

Gold-*beating*, and Gold-*beater's fkin.* See Gold-*leaf.*

Gold, *Burnifhed*, is that which is polifhed with a fteel inftrument, called a burnifher, if it be wrought gold, or gilding on metal; or with a wolf's tooth, if it be gilding in water. See Gilding.

Gold *Chain.* See Chain.

Gold *Coin*, or *fpecies of gold.* See Coin and Coinage.

Gold *Colour on Glafs and China.* See Gems, Glass, Gilding, and Porcelain.

Gold-*coloured Glazing.* See Glazing.

Gold-*coloured Metal* is produced by melting zinc with copper. According to the purity of the zinc and copper, the proportions in which they are mixed, and the intimacy of their union, the compound metal proves more or lefs malleable, and approaches more or lefs to the colour of gold. Some direct the zinc to be taken only in a fifth or fixth part of the weight of the copper, and others in an equal weight or more. Dr. Lewis obferves, from the refult of many experiments, that both with the fmalleft and largeft of thefe quantities of zinc, the metal proves more like gold than with the intermediate proportions.

The colour of thefe compounds is improved by a fmall mixture of fome other metallic bodies. Cramer recommends the addition of a fmall quantity of pure tin to copper, melted with a fourth or fixth part of zinc, which forms a compound metal, that acquires, on being well cleaned, and laid in the air for fome days, a fuperficial colour of fine gold. Geoffroy fays that iron has the beft effect: with the proportions of ten parts of zinc, eight of copper, and one of iron-filings, he produced a metal of a fine fmooth grain, compact, hard, and bright, and of a beautiful gold colour. By making the copper firft into brafs, and then melting it with a fuitable quantity of zinc, a metal may be obtained of fu-

perior quality to that produced either by melting the copper and zinc, or by impregnating the copper with zinc, by cementation and fusion with calamine; which is a method sometimes practised. A very ingenious artist, says Dr. Lewis, who now prepares a gold-coloured metal in great perfection, has a fine kind of brass made on purpose for this use. The union of the copper and zinc in fusion, succeeds best and with least loss of the zinc, according to Dr Lewis, by using a mixture of black flux and borax, or a composition of twelve parts of green glass powdered, six parts of potash two of borax, and one of powdered charcoal: when this flux is fused in the crucible, the copper and zinc are dropped into it; and when they appear perfectly melted, they are to be well stirred together with an iron rod, and expeditiously poured out. The same flux will serve for melting several fresh quantities of the metal. Dr. Hooke gives the following receipt for making a gold-coloured metal: eight parts of distilled verdigris, *i. e.* of verdigris purified by solution in distilled vinegar and crystallization, and four parts of Alexandrian tutty, with two of nitre, and one of borax, are directed to be mixed with oil to the consistence of pap; then melted in a crucible, and poured into a flat mould first well warmed. A composition of this kind is called *aurum sophisticum*.

The following method is recommended by Homberg for giving a gold colour to copper, without the addition of zinc; make an amalgam of one part pure copper, and three parts quicksilver; boil this in river-water for two hours, then distil off the quicksilver in a retort, and cohobate it once; take out the copper and fuse it, and it will be found of a beautiful gold colour, more ductile than common copper, and extremely well fitted for watch-work, gilding, and the finer machines and utensils. The celebrated Mr. Pott affirms that a gold-coloured metal may be made from a mixture of copper and tin, and directs it to be compounded in the following manner: Take one half ounce of tin ashes, and four half ounces of copper; melt them well together in a close luted crucible, with a strong fire; or take one half ounce of the purest tin cut in pieces, and sixteen half ounces of pure copper beaten into thin plates; lay the tin between the copper-plates, lute the crucible close, and melt with a strong fire. See *Prince's* METAL and TOMBAC.

Silver is tarnished superficially, by certain vapours, as that of putrified urine, to a colour so like that of gold, that several edicts have been issued in France to prevent frauds of this kind with regard to wire and laces.

GOLD-*coloured Pigments*. See PIGMENTS.

GOLD-*coloured Varnish*. See LACQUER.

GOLD, *Crown*, See COIN and STANDARD.

GOLD, *Dutch*, is a kind of leaf used in gilding, &c. which is copper gilt, or brass beaten into leaves like the genuine gold-leaf. It is said to be made from copper-plates, by cementation with calamine, without subsequent fusion. The thickness, compared with that of leaf-gold, is as nineteen to four, and under equal surfaces it is considerably more than twice as heavy as the gold.

GOLD, *Farthing of*. See FARTHING.

GOLD, *Fine* or *Pure*, is that purged by the fire of all its impurities, and all alloy. The Latins call it *aurum purum, aurum primum, aurum obrizum, aurum coctum*.

The moderns frequently call it *gold of twenty-four carats*; but, in reality, there is no such thing as gold so very pure; and there is always wanting at least a quarter of a carat. Gold of twenty-two carats has one part of silver, and another of copper: that of twenty-three carats has half a part, *i e.* half a twenty-fourth of each.

Bouterouc maintains, that the electrum of the ancients was gold of nineteen carats; or four parts gold, and a fifth silver.

From an ordinance of king John of France, it appears that the gold then struck at Paris was of nineteen carats one-fifth; and yet it is added that it was the best and finest gold then known on earth. See STANDARD.

GOLD, *Fulminating*, *aurum fulminans*, a precipitate of gold from its nitro-muriatic solution by ammonia, which possesses a most remarkable explosive property. See AURUM.

It is prepared by diluting a solution of muriated gold with six or eight times its bulk of distilled water, adding drop by drop liquid ammonia, till the precipitation ceases; then let the yellow powder thus obtained be separated by a filter, well washed in hot water, and afterwards dried. The fulminating gold, thus procured, will exceed the weight of the original gold by about 33 parts in 100. If a small quantity, *e. g.* half a grain, of this powder be held over a candle, in a spoon or on the blade of a knife, it presently explodes with a very loud report. This powder should be very cautiously used; the temperature requisite for its explosion is stated at above 250° of Fahrenheit. Before it explodes, its yellow colour changes to black, and at the moment of its decomposition an instantaneous flash is observed. The principal energy in explosion is directed downwards, insomuch that two or three grains of it exploded on a moderately thick sheet of copper will burst a hole in it. This salt is decomposed by an electrical shock, but it cannot be ignited by a spark from electricity or from flint and steel. It will vehemently explode by sudden friction, and therefore, in order to avoid dangerous accidents of this kind, it should never be kept in a ground-stoppered bottle. The facility of its explosion is very much increased by high drying; so that if it be heated till it becomes black, and is immediately removed from the fire, it will frequently go off by a mere touch. If the fulminating gold be mixed with four or five times its weight of chalk, or sulphat of potash, or with any pulverulent substance neither fusible nor decomposable at a moderate temperature, and exposed gradually to a low heat, it will be quickly decomposed, leaving merely the purple oxyd of gold. The same effect may be produced by very cautiously heating the fulminating gold without any addition, removing it from the fire when it has changed its colour, and when cold heating it again, and proceeding in this way till the powder becomes purple, in which state it will have entirely lost its explosive faculty. A similar change occurs by melting sulphur at the lowest possible heat, and dropping in the fulminating gold by half a grain at a time, well mixing it; the sulphur may then be burnt off without danger, and minute grains of metallic gold will be left behind. "The true theory of the decomposition of fulminating gold was partially discovered by Bergman, and has since been fully illustrated by Berthollet. The former of these able chemists shewed that this salt when decomposed in close vessels was reduced to gold, partly in the metallic state and partly in that of purple oxyd, and at the same time a gas was extricated in bulk about a thousand times as great as that of the original fulminating salt, and which extinguished flame and animal life, was not absorbed by water, and gave no precipitate with lime-water. Berthollet, by decomposing the same substance in a copper tube, connected with a jar inverted in mercury, obtained azotic gas and a few drops of water, and the gold was reduced to the metallic appearance. Now as ammonia is composed of hydrogen and azot, and as the affinity of gold for oxygen is very slight, it is manifest that the decomposition and explosion, under the circumstances already mentioned, are occasioned by the oxygen of the

gold and the hydrogen of the ammonia combining to form water, and to the liberation of the azot and its sudden assumption of the gaseous state." Aikin's Dict.

GOLD, *Leaf*, or *beaten gold*, is gold beaten with a hammer into exceedingly thin leaves. It is astonishing to consider the fineness to which a body of gold is thus reduced. In an experiment of Reaumur's, forty-two square inches and three tenths of gold-leaf weighed one grain Troy; and Mr. Boyle found that fifty and seven tenths weighed but a grain. As a cubic inch of gold weighs 4902 grains, the thickness of the gold-leaf examined by the one was the 207355th, and of that by the other only the 248532nd part of an inch. See DUCTILITY *of Gold*.

This gold is beat on a smooth block of black marble, from two hundred to six hundred pounds in weight, and about nine inches square on the upper surface, fitted into the middle of a wooden frame, about two feet square, so as that the surface of the marble and frame form one even plane. Three of the sides are furnished with a high ledge, and the front, which is open, has a leather flap fastened to it, which the gold beater uses as an apron, for preserving the fragments of gold that fall off. Three hammers are employed in this business, having two round and somewhat convex faces: the first, called the cutch hammer, is about four inches in diameter, and weighs fifteen or sixteen pounds: the second, called the shodering hammer, weighs about twelve pounds, and is about the same diameter: the third, called the gold or finishing hammer, weighs ten or eleven pounds, and is nearly of the same width. The French use four hammers, differing both in size and shape from those of our workmen.

The gold beaters also use three kinds of animal membranes; some of which are laid between the leaves to prevent their uniting together, and others over them to defend them from injury by the action of the hammer. For the outside cover, they use common parchment made of sheep skin; for interlaying with the gold, first, the smoothest and closest vellum made of calves skin; and afterwards, the much finer skins of ox-gut, stript off from the large straight gut slit open, prepared on purpose for this use, and hence called *gold-beater's skin*. The general process of their preparation, is said to consist in applying one upon another, by the smooth sides, in a moist state, in which they readily cohere and unite inseparably, stretching them on a frame, and carefully scraping off the fat and rough matter, so as to leave only the fine exterior membrane of the gut; beating them between double leaves of paper, to force out the remaining unctuosity; moistening them once or twice with an infusion of warm spices, and lastly, drying and pressing them. It is said, that some calcined gypsum, or plaster of Paris, is rubbed with a hare's foot, both on the vellum, and ox-gut skins, which fill up their pores, and prevent the gold leaf from sticking. These skins, after seventy or eighty repetitions, become unfit for use; but their virtue may be restored by interlaying them with leaves of paper moistened with vinegar or white wine, beating them for a whole day, and afterwards rubbing them over with plaster of Paris: and even holes in them may be repaired by the dextrous application of fresh skins.

GOLD, *the manner of preparing and beating*. They first melt a quantity of the purest gold in a black-lead crucible, with some borax, in a wind furnace, and pour it into an iron ingot mould, six or eight inches long, and ¾ of an inch wide, previously greased and heated; the bar of gold is made red-hot and forged on an anvil into a long plate, which is farther extended, by being passed repeatedly between polished steel rollers, till it becomes a ribband, as thin as paper. This ribband is divided by compasses, and cut with shears into equal pieces, which are forged on an anvil till they are an inch square, and afterwards well annealed. Two ounces of gold, which is the quantity melted at a time, make a hundred and fifty of these squares, so that each of them weighs six grains and two fifths; and as 4902 grains of gold make a cubic inch, the thickness of the square pieces is about the 766th part of an inch. All these squares are interlaid with leaves or vellum, three or four inches square; one leaf being laid between every two of them, and about twenty more of the leaves are laid on the outsides: over these is drawn a parchment case open at both ends, and over this another, in a contrary direction, so that the vellum and gold leaves are kept tight and close. The whole is then beaten with the heaviest hammer, till the gold is stretched to the extent of the vellum: the pieces taken out of this case or mould, are cut in four with a steel knife; and the six hundred pieces thus produced are interlaid, in the same manner, with pieces of the ox-gut skins, five inches square. The beating is repeated with a lighter hammer, till the golden plates have acquired the extent of the skin; when they are divided into four, by a piece of cane cut to an edge. The whole number of leaves is then divided into four parcels, which are interlaid, as before, and beaten separately, till they are stretched for the third time to the size of the skins. The French repeat the division and beating once more. After the last beating, the leaves are taken up by the end of a cane instrument, and being thrown flat on a leathern cushion, are cut to a size, one by one, with a square frame of cane made of a proper sharpness, or with a frame of wood edged with cane. They are then fitted into books of twenty-five leaves each, the paper of which is well smoothed, and rubbed with red bole to prevent their sticking to it. The size of the French gold leaves is from somewhat less than three inches to 3¾ square; that of our's from three inches to 3⅓. We shall here observe, that the gold used for the above purpose is never pure, because pure gold is too ductile to be worked between the gold-beater's skins. The newest skins will work the finest gold, and make the thinnest leaf, because they are the smoothest. Old skins, being rough or foul, require coarser gold. The finest gold for this purpose has three grains of alloy in the ounce, and the coarsest 12 grains. In general the alloy is six grains, or one eightieth part. The alloy of leaf-gold is silver, or copper, or both, and the colour is produced of various tints accordingly. Two ounces and two pennyweights of gold are delivered by the master to the workman, who, if very skilful, returns 2000 leaves, or 80 books, of gold, together with one ounce and six pennyweights of waste cuttings. Hence one book weighs 4.8 grains; and as the leaves measure 3.3 inches in the side, the thickness of the leaf is one two hundred and eighty-two thousandth part of an inch.

The French prepare what is called green gold-leaf, from a composition of one part of copper and two of silver, with eighty of gold; but Dr. Lewis observes, that such an admixture gives no greenness to gold, and that this kind of leaf is made from the same fine gold as the highest gold-coloured sort, the greenish hue being a superficial teint given to the gold in some part of the process: this leaf is chiefly used for the gilding of books. A kind of leaf, called *party-gold*, is formed by laying a thick leaf of silver, and a thinner one of gold, flat on one another; they are then heated and pressed together, so as to unite and cohere: and being beaten into fine leaves, as in the foregoing process, the gold, though only in quantity a fourth

of that of the filver, extends over it and every where covers it.

GOLD, *Million of*, a phrafe often ufed to fignify a million of crowns.

GOLD *Money*. See MONEY and COIN.

GOLD, *Mofaic*, is gold applied in pannels on proper ground, diftributed into fquares, lozenges, and other compartments; part of which is fhadowed to raife or heighten the reft. See MOSAIC.

GOLD *Plates for Enamelling* are generally made of ducat gold, whofe finenefs is from $23\frac{1}{2}$ to $23\frac{3}{4}$ carats: and the fineft gold is the beft for this purpofe, unlefs where fome parts of the gold are left bare and unpolifhed, as in watch-cafes, fnuff-boxes, &c. for which purpofe a mixture of alloy is neceffary, and filver is preferred to copper, becaufe the latter difpofes the plates to tarnifh, and turn green. See ENAMELLING.

GOLD, *Potable, aurum potabile*. See AURUM *Potabile*, and GOLD.

GOLD *Powder*, for the purpofes of gilding, may be made by grinding gold leaf with honey, or thick gum-water, (fee *Shell*-GOLD): by diftilling to drynefs a folution of gold in aqua regia: by evaporating the mercury from an amalgam of gold, taking care well to ftir the mafs near the end of the procefs with a glafs rod or tobacco pipe; or by precipitating gold from its folution in aqua regia by applying to it a folution of common green vitriol in water, or fome copper, &c.

GOLD *Precipitate with Tin*, called alfo, from its fuppofed difcoverer, *calx Caffii*, is prepared with great care both in diffolving the tin, and diluting the folution. For this purpofe, a mixture of two parts of aquafortis, and one of fpirit of falt, is fuppofed to be the beft menftruum for the tin. Into this mixture fome fine block tin, granulated, is to be let fall, grain by grain, waiting till one grain is diffolved before another is dropped in, that the diffolution may go on flowly, without any heat or difcharge of fumes. The gold is diffolved in common aqua regia; and a few drops of this folution being mixed with fome ounces of pure water, as many drops of the folution of tin are added. If the mixture changes immediately to a clear bright purplifh red colour, the due degree of dilution has been determined; if the colour appears dull, a greater quantity of water muft be added for the reft of the folutions. After the mixture has depofited its red matter, and become clear, a little more of the tin folution is to be dropped in, for difcovering and precipitating any gold that may ftill remain in it; the liquor being then poured off, the precipitate is wafhed and dried. Lewis's Com. Phil. Techn. p. 176. See *Ruby* GLASS.

GOLD, *Queen*. See QUEEN *gold*.

GOLD, *Shell*, is that ufed by the gilders and illuminers, and with which gold letters are written. It is made by grinding gold leaves, or gold beater's fragments, with a little honey, and afterwards feparating the honey from the powdered gold by means of water. When the honey is wafhed away, the gold may be put on paper, or kept in fhells; whence its name. When it is ufed, it is diluted with gum-water, or foap-fuds. The German gold-powder, prepared from the Dutch gold leaf in the fame manner, is generally ufed, and when it is well fcoured with varnifh, anfwers the end in japanner's gilding, as well as the genuine. See GILDING.

GOLD-*fize* for burnifhed gilding, is prepared of one pound and a half of tobacco-pipe clay, half an ounce of red chalk, a quarter of an ounce of black lead, forty drops of fweet oil, and three drams of pure tallow; grind the clay, chalk, and black-lead feparately, very fine in water; then mix them together; add the oil and tallow, and grind the mixture to a due confiftence; or it may be more fimply prepared by grinding together fome ftrongly calcined red ochre with the thickeft and oldeft drying oil that can be procured; and, previoufly to ufe, mixing it with a little oil of turpentine for giving it a proper confiftence. See *Oil* GILDING.

GOLD-*fize of Japanners* may be made by pulverizing gum animi and afphaltum, of each one ounce; red-lead, litharge of gold, and umbre, of each one ounce and a half, mixing them with a pound of linfeed oil, and boiling them, obferving to ftir them till the whole be incorporated, and appears, on growing cold, of the confiftence of tar; ftrain the mixture through a flannel, and keep it ftopped up in a bottle, for ufe. When it is ufed, it muft be ground with as much vermilion as will give it an opaque body, and diluted with oil of turpentine, fo that it may be worked freely with the pencil. A fimple preparation confifts of one pound of linfeed oil, and four ounces of gum animi; powder the gum, and mix it gradually with the boiling oil: let it continue to boil, till it becomes of the confiftence of tar; ftrain it through a coarfe cloth, keep and ufe it as the other.

GOLD-*fmith*, or as fome choofe to exprefs it, *filver-fmith*, the artift who makes veffels, utenfils, and ornaments in gold or filver. The goldfmiths work is either performed in the mould, or beat out with the hammer or other engine. All works that have raifed figures are caft in moulds, and afterwards polifhed and finifhed; plates or difhes of filver or gold are beat out from thin flat plates, and tankards and other veffels of that kind are formed of plates foldered together, and their mouldings are beat, not caft. The bufinefs of the goldfmith formerly required much more labour than it does at prefent, for they were obliged to hammer the metal from the ingot to the thinnefs they wanted: but there are now invented flatting-mills, which reduce metal to the thinnefs that is required, at a very fmall expence. The goldfmith is to make his own moulds, and for that reafon ought to be a good defigner, and have a tafte in fculpture: he alfo ought to know enough of metallurgy to be able to affay mixed metals, and to mix the alloy.

The goldfmith in London employs feveral hands under him for the various articles of his trade. In this great city there are always hands that excel in every particular branch of the trade, and there is commonly employment enough for every one in his particular branch. The jeweller, the fnuff-box and toy-maker, the filver turner, the gilder, the burnifher, the chafer, the refiner, and the gold-beater, are all employed by and under the goldfmith.

GOLD-*fmith, Company of, in London*. See COMPANY.

GOLD *Thread*, or *fpun gold*, is a flatted gilt wire, wrapped or laid over a thread of yellow filk, by twifting it with a wheel and iron bobbins. By means of a curious but complex machinery, a number of threads is thus twifted at once by the turning of one wheel. The principal art confifts in fo regulating the motion, that the feveral circumvolutions of the flatted wire, on each thread, may juft touch one another, and form, as it were, one continued covering. At Milan, it is faid, they make a fort of flatted wire, gilt only on one fide, which is wound upon the thread, fo that only the gilt fide appears. There is alfo a gilt copper wire, made in the fame manner as the gilt filver, chiefly at Nuremberg: and the ordinances of

France require it to be ſpun on flaxen or hempen threads. The Chineſe, inſtead of flatted gilt wire, uſe ſlips of gilt paper, which they interweave in their ſtuffs, and twiſt upon ſilk threads.

Gold, *Tun of*, is a kind of money of account, formerly uſed by the Dutch, and in ſome other countries, containing a hundred thouſand florins.

A hundred pounds of, or in, gold, is found to weigh two pounds ten ounces: the ſum in ſilver weighs twenty-ſix pounds four ounces. Twenty-two pence in copper farthings and half-pence, weigh one pound avoirdupois. A tun of gold, at 4*l.* the ounce, amounts to 96,000*l.* A tun of ſilver, at 5*s.* 2*d.* the ounce, to 6200*l.* A pound ſterling of gold to 48*l.* An ounce is worth 4*l.* The penny-weight 4*s.* One grain, 2*d.* A pound of ſterling ſilver amounts to 3*l.* 2*s.* An ounce is worth 5*s.* 2*d.* The penny-weight, 3*d.* and ſomething more; one grain a half-penny. A pound of ſilver avoirdupois comes to 3*l.* 5*s.* 3*d.* half-penny.

Gold, *Virgin*, is pure gold, juſt as it is taken out of the mines, before it has undergone any action or preparation of fire; whence the Greeks call it απυρος.

Such is the αμμοχρυσος, or gold-duſt, and that got by lotion in the lavaderos in Chili: it is added, that there are maſſes or lumps of pure gold found in the mines, particularly thoſe of Hungary. Accordingly, in the emperor's collection, are ſtill preſerved ſeveral plates of gold, ſaid to have been thus found.

Virgin gold is ſometimes very pale, and ſo ſoft, that it may be moulded into any figure with the hand; it even takes an impreſſion from a ſeal, like the ſofteſt wax. To harden it, as alſo to heighten its colour, they mix emery with it.

Gold, *White*. See Platina.

Gold *Wire* is a cylindrical ingot of ſilver, above an inch thick, two feet in length, and weighing about twenty pounds, ſuperficially gilt, or covered with gold at the fire, and afterwards drawn ſucceſſively through a great number of little round holes of a wire-drawing iron, each leſs than the other, till it be ſometimes no bigger than a hair of the head. There is very little wire made entirely of gold, and this chiefly for one particular purpoſe, that of filligree work.

It is amazing to what degree of fineneſs the gold is here drawn; and yet it ſtill keeps firm together, and never ſhews the leaſt ſigns of the ſilver underneath it. The reader may ſee a computation hereof, as alſo a more particular account of the manner of proceeding, under the article Ductility *of gold*.

Gold *Wire flatted*, is the former wire flatted between two rollers of poliſhed ſteel, to fit it to be ſpun in ſilk, or to be uſed flat as it is without ſpinning, in certain ſtuffs, laces, embroideries, &c.

Manner of forming Gold Wire and Gold thread, both round and flat.—The firſt object, which is of the utmoſt conſequence, is the choice of the pureſt gold; for on this chiefly depends the beauty and durability of the colour of the laces, brocades, and other commodities prepared from it. To a difference in this reſpect, the boaſted ſuperiority of the French laces to the generality of thoſe made in England, till of late, has been wholly owing. With regard to the ſilver that forms the body of the wire, it is ſaid that there is an advantage in its being alloyed. The French ſilver for gilding is ſaid to be alloyed with five or ſix penny-weight, and ours with twelve penny-weight of copper, in the pound Troy. The gold is employed in thick leaves, which are applied all over the ſilver rod, and preſſed down ſmooth with a ſteel burniſher. Several of theſe leaves are laid over one another, as the gilding is required to be more or leſs thick. The ſmalleſt proportion allowed by act of parliament, is 100 grains of gold to a pound, or 5760 grains of ſilver. The largeſt proportion for the beſt double gilt wire was formerly 120 grains to a pound; but the proportion of gold has been of late increaſed to about 140 grains. The firſt part of the drawing proceſs, as well as the preparation and gilding of the ſilver rod, is performed by the refiner, who uſes plates of hardened ſteel, with a piece of tough iron welded on the back, to prevent the ſteel from breaking. The holes in theſe plates are conical, being larger in the back part than in the ſteel, that the rod may not be ſcratched againſt the outer edge, and that they may contain bees-wax, which makes the rod paſs more freely, and preſerves the gold from being rubbed off. One end of the rod, made ſmaller than the reſt, is puſhed through a hole that will admit it, when the plate has been properly ſecured, and laid hold of by ſtrong pincers, called clamps, adapted to the purpoſe; to theſe pincers, which are ſo contrived, that the force which pulls them horizontally, ſerves at the ſame time to preſs them together, a rope is faſtened by one end, and the other end goes round a capſtan with croſs bars, which requires the ſtrength of ſeveral men to turn it. The rod, thus drawn through, is well annealed; it is then paſſed through the next hole; and the annealing and drawing are repeated, till, being reduced to about the ſize of a large quill, it is delivered in coils to the wire-drawers. The remainder of the proceſs requires plates of a different quality, which are brought from Lyons in France, and are formed of a metallic maſs, whoſe prevailing ingredient is iron: the holes are drilled in them here. Theſe plates are of two ſorts; ſome of conſiderable thickneſs, for the wire in its larger ſtate, and others about half as thick, for the finer wire. In the uſe of theſe plates, furniſhed with a variety of holes, the dexterity of the workman principally conſiſts in adapting the hole to the wire: for this purpoſe he uſes a braſs plate, called a ſize, on which is meaſured, by means of notches, like ſteps cut at one end, the increaſe which a certain length of wire ſhould gain in paſſing through a freſh hole; and if the wire is found to ſtretch too much or too little, the hole is widened or contracted. Slits of different widths, in thick poliſhed iron rings, ſerve alſo as gages for meaſuring the degree of fineneſs of the wire.

The wire-drawer's proceſs begins with annealing the large wire received from the refiner, which he does, by placing it, coiled up, on ſome lighted charcoal, in a cylindrical cavity, called the pit, under a chimney, and throwing more burning charcoal over it. When it is cooled by being quenched in water, one end is paſſed through the firſt hole in the thick plate, and faſtened to an upright wooden cylinder ſix or eight inches in diameter; in the top of which are two ſtaples, and through theſe is paſſed the long arm of a handle, by which the cylinder is turned on its axis by ſeveral men. By this proceſs, called *degroſſing*, the wire is frequently annealed and quenched, after paſſing through every hole, or every other hole, till it is brought to about the ſize of the ſmall end of a tobacco pipe, and then cut into portions for the fine wire-drawer. In this laſt part of the wire-drawing proceſs, annealing is not neceſſary, but the wire is waxed at every hole. The contrivance for drawing the wire through the plate in this caſe, when leſs force is needful, is a kind of a wooden wheel placed horizontally, having in its upper ſurface ſmall holes at different diſtances from the axis, into one or other of which, according to the force required,

is inferted the end of an upright handle, whofe upper end is received in a hole made in a crofs bar above. From this the wire is wound off upon a fmaller cylinder, called a rochett, placed on the fpindle of a fpinning-wheel; and this cylinder being placed behind the plate, the wire is again drawn through upon the firft, and being brought to the proper finenefs, it is annealed for the flatting-mill. In this annealing, the wire is wound on a large hollow copper bobbin, fet upright, including fmall-coal, and encompaffed with lighted charcoal or fmall-coal, communicating a gradual heat The wire, in this ftate, muft be watched and removed from the heat, when it appears of the proper colour The next operation is that of the flatting-mill, which confifts of two perfectly round and exquifitely polifhed rollers, formed internally of iron, and welted over with a plate of refined fteel: thefe rollers are placed with their axes parallel, and their circumferences nearly in contact; they are both turned with one handle; the lowermoft is about ten inches in diameter, the upper little more than two, and their width or thicknefs is about an inch and a quarter. Thefe rolls are fometimes repolifhed with putty, prepared by calcining a mixture of lead and tin. The wire, unwinding from a bobbin, and paffing between the leaves of a book gently preffed, and through a narrow flit in an upright piece of wood, called a ketch, is directed by a fmall conical hole in a piece of iron, called a guide, to any particular part of the width of the rollers, fome of the beft of which are capable of receiving, by this contrivance, forty threads. When the wire is flatted between the rollers, it is wound again on a bobbin, which is turned by a wheel, fixed on the axis of one of the rolls, and fo proportioned, that the motion of the bobbin juft keeps pace with that of the rolls. Dr. Halley ftates that fix feet in length of the fineft gilt wire before flatting will counterpoife no more than a grain; and as the gold is not quite 1-57th of the whole, a fingle grain of gold thus extended will be 345.6 feet long. By flatting, the length of the wire is increafed about one-feventh, and its weight is equal to 1-96th of an inch; hence the furface occupied by one grain is equal to 98.7 fquare inches, with a thicknefs of 1-490444th of an inch. (See Ductility.) See on the fubject of the preceding articles, Macquer's Dict. of Chemiftry, Eng. edit. 1777. and particularly Dr. Lewis's Philofophical Commerce of Arts, *paffim*. See alfo Aikin's Dictionary.

Grand Junction Canal

Grand *Junction Canal.* To the full account which we gave of this very important inland navigation in our article Canal, we have here merely to add a few particulars which have occurred since that account was printed. The act of the 50th Geo. III. for the Grand Union canal provides, that a canal with locks is to be substituted for the railway-branch from Gayton to Northampton, in order to open a communication by water, from the head of the new navigation, the design for the continuation of the Leicestershire and Northamptonshire Union canals further south than Market Harborough, where it now terminates, being dropt, in consequence of the adoption of the Grand Union above-mentioned, which will connect the above canal with the Grand Junction. The three aqueduct arches over the Ouse at Wolverton having been made flat elliptical, instead of the curves of equilibration, and the foundation also insufficient, they gave signs of great insecurity immediately on their centres being struck, and in February 1808 two of them actually fell in and emptied the canal, as far as the stop-gates: fortunately, the old line of locks across the valley had not been disturbed, and the trade has suffered no interruption in consequence. A cast-iron aqueduct on brick and stone piers is now substituting for these three arches, under the direction of Mr. Benjamin Bevan, who is now the engineer to the company. In 1807 a new reservoir was compleated near the side-ponds on the northern side of the Tring summit, for supplying water to the locks below the side-ponds in dry seasons.

In examining the strata and springs on the north side of the chalk summit, between Tring and Wendover, with a view to better supplying the Wendover branch and summit-level with water, Mr. Bevan discovered, that different water-tight beds in the lower chalk held up springs a considerable height above the canal, owing to their dip to the southward; and in order to avail himself of this water, a sough or tunnel was began in the upper bank of the canal near Wendover, and has been driven about half a mile southward, interfecting different strata of chalk from beneath, and increasing in its supply of water as it proceeded; but observing that the principal vent of this water was in the winter and early spring months, when the other sources were more than sufficient for the supply of the canal, it occurred to that ingenious gentleman to place a strong and water-tight valve in the most favourable part of this tunnel, which, as soon in the autumn as the canal is amply supplied from its other feeders, is shut, and kept so, until these begin again to slacken in their supply; the water in the immense planes of these beds of chalk, in the mean time accumulating, as in a vast subterranean reservoir, the springs rise to the level which they originally did before this tunnel was begun, about 20 feet above the canal; and for many weeks

after the opening of the valve, in the beginning of summer, they pour forth a most surprising stream of water into the canal, which otherwise would have vented miles off in the chalk vallies, or slowly have made its way down through the joints and fissures in the strata to springs at the bottom of the chalk, which vent below the level of the canal.

In 1808 a twelve-horse single Bolton's steam-engine was erected near Nash-mill, in Hertfordshire, to lift the water again, the rise of four locks, for better supplying the mills during seven or eight months of the year. The company, in 1806, caused boats to be fitted up for conveying fat sheep alive, in tiers one above another, from distant places in the county, to the London markets, instead of fatiguing them by driving along the roads, the scheme of thus bringing oxen having been previously tried, and found not to answer; but after a fair trial, the expences were found to over-balance the advantages expected from this also; we are sorry also to add, that the cattle-market at Paddington has failed, and that the pens erected for it by the company have been sold and removed.

The limited quantity of coals brought to Paddington, or within 20 miles of London by this canal, now pay a duty of 10*s.* 9¾*d* per ton (of 20 × 112lb.), which is equivalent to the duty on Newcastle coals in the Thames: in consequence of this heavy and oppressive duty, many waggons and carts are employed in fetching coals by land, from the next wharf beyond the limited distance, near Watford. The Grand Union canal above-mentioned is begun, and is to join this canal near the S.W. end of the Braunston tunnel. The design of a branch from near Tring, through Aylesbury and Thame, to the Thames and Isis navigation and Wilts and Berks canal near Abingdon, has been again revived, and it seems probable, that an act for that purpose will pass in the ensuing sessions of parliament (1811).

Towards supplying water to the inhabitants near Paddington, a transfer of the company's rights has been made to a separate water-company, which is expected to be confirmed by parliament in the ensuing sessions.

In November 1806, the company declared the first half yearly dividend of 1½ *per cent.* on the original shares, which has regularly increased to 3 *per cent.* half-yearly, exclusive of property tax. The affairs of the company seem now fast retrieving from the effects of their great mismanagement for many years after its establishment, and to be now in a very prosperous state; the shares (of 100*l.*) were, in September 1810, reported to be currently sold at 302*l.* each! although, at one period, the same could with difficulty be disposed of at 65*l.* to 70*l.* each: such are the effects of good or bad management, and of abilities and integrity in those entrusted with the direction and management of an immense concern like this, in inspiring confidence in commercial men to enter into trade and speculations connected with the canal, and in capitalists to invest their money in the company's shares. A resolution of the general assembly of proprietors, on the 7th of June 1803, for appointing a general superintendant of their concerns, principally led to this beneficial change. On the 11th of June following, Charles Harvey, esq. was appointed to this office by the committee, and, after much opposition from certain powerful individuals, was, on the 11th of July, confirmed therein, by a general assembly called for the special purpose.

GRAND *Key*, a small island among the Bahamas. N. lat. 26 54′. W. long. 77° 48′.

GRAND *Lake*, a lake of Louisiana. N. lat. 32°. W. long. 93° 5′.—Also, a lake in the province of New Brunswick, near the river St. John's, said to be 30 miles long, eight or ten broad, and in some places 40 fathoms deep.

GRAND *Luce, Le*, a town of France, in the department of the Sarthe, and chief place of a canton, in the district of Saint-Calais; 14 miles S.E. of Le Mans. The place contains 2045, and the canton 10,493 inhabitants, on a territory of 227½ kiliometres, in 8 communes.

GRAND *Manan Island*, an island of the Atlantic ocean; 6 miles S. by S.E. of Campo Bello island, opposite to Papamaquoddy bay on the eastern border of the United States.

GRAND *Ridge*, is a term often used, (see our article CANAL,) for the water-head, or summit line, across an island or continent, from whence the rain waters fall by opposite courses to the ocean. It results from the admirable system of vallies, which the great Creator has spread over the whole face of the earth, leaving no part, perhaps, originally of the surface, without a descent and out-fall to the sea; that the ridges, or summit-lines, form a system not less beautiful and perfect than the vallies; and whence it happens, that, from any hill whatever, it is practicable to mark on a good map, and to travel to every other hill in the same island or continent, however large, without crossing any running water, however small, but constantly to pass along a ridge or watershead; whence the waters on the surface fall opposite ways from your route. It seems surprising, that no one has attempted to illustrate this subject by a good map, shewing all the connections and windings of these ridges in England, or even any local district, until of late, that Mr. Farey has prepared a square of map, including Derbyshire, shewing the ridges, and the situation of all the hills and principal eminences upon them, which is intended to accompany his report to the Board of Agriculture on that interesting district.

The triangular form of the British island, and the situation of the two principal rivers, the Thames and the Severn, (or rather the Bristol channel,) occasion the grand ridge of England to divide into two branches on the Chalk Downs, a few miles N E. of Devizes; one of which, (the south-western,) proceeds to Rundaway-hill, and crosses the deep cutting of the Kennet and Avon canal, near to Devizes, near East Lavington, Warminster, Wincanton, Beaminster, Crewkerne, Chard, &c. by a most circuitous route, passing almost to the north and to the south coasts alternately, until it reaches the Land's End in Cornwall: having, in this long route, probably descended to no lower strata than the red ground or marle, of which we shall speak further presently.

The other, or south-eastern branch of the grand ridge, proceeds along the chalk and the clays and sands above it, across the deep-cutting of the Kennet and Avon canal, near Burbage, by High-clere, (near which it probably occupies the highest stratum in the whole British series,) near to Alton and Haslemere, when it soon descends off the chalk into the great southern denudation, (see Philosophical Magazine, vol. xxxv. p. 130.), and pursues the under measures, through the wealds of Sussex and Kent, by Alford, Leith-hill, Handscross, (on the London and Brighton roads, being there on the lowest stratum but one which appears in that road,) by Turner-hill, Nutley, Crowborough, Rotherfield, Wadhurst, Tenterden, Shadoxhurst, Lympe (near Hythe), where it again ascends the edge of the chalk, and proceeds on it by Paddlesworth, Swingfield, and Lydden, to the coast at King's Down, near Walmer castle.

From the point of branching, N.E. of Devizes, as above described, the grand ridge follows the chalk northward by White-horse hill, near Cherhill, &c. till within a few miles

of Swindon, when it turns to the N.W., and deſcends to the marle, and other ſtrata below the chalk, croſſing the Woburn ſand ſtratum, not far from Wooton-Baſſet: and, paſſing to the Bath free-ſtone range, it croſſes the Salperton tunnel, on the Thames and Severn canal, and proceeds near to the weſtern edges of the ſame ſtrata, by Charlton-Kings, near Cheltenham, Stanway-hill, Broad-way-hill, Lemington-hill, Long-Compton-hill, and Epwell; ſoon after which, the grand ridge begins to leave the free-ſtone, and take to the dark blue clays, &c. under it, except croſſing ſome points of the ſtone, and traverſes the Fenny-Compton tunnel, on the Oxford canal; thence by Hellidon, and near Daventry, it croſſes the Braunſton tunnel, on the Grand Junction canal, at Weſt-Haddon, and at Huſband's-Boſworth, the tunnels of the Grand Union canal; when, turning north-weſt, the ridge paſſes Gilmorton; and not far from Lutterworth it croſſes the Lias clays and lime-ſtone ſtrata, and deſcends to the red marle (above mentioned), and quickly, by a great fault, or ſudden lift of the ſtrata, is brought upon the coal-meaſures of the Bedworth-field, and croſſes the deep cutting of the Coventry canal, through Bedworth town, acroſs the late ſir Roger Newdigate's canal, and ſweeps round to the weſt, ſouth-weſt, and ſouth, to Kenilworth; when, having croſſed another fault, and got again upon the red marle, it croſſes the deep-cutting of the Warwick and Birmingham canal, near Baddeſley-Clinton, and of the Stratford canal, near Hockley; thence by Aſhley-heath, and croſſes the Weſt-heath tunnel of the Worceſter and Birmingham canal, and the Lapal tunnel of the Dudley canal: after which, the grand ridge croſſes the baſaltic hills between Rowley and Dudley, (which belong to the red marle ſtrata,) and, deſcending to the coal-meaſures, croſſes the Dudley tunnel N.W. of that town, and proceeds by Sedgley; then croſſing an erect and denudated patch of the yellow lime-ſtrata, it croſſes the deep-cuttings of the Old Birmingham canal, the Wyrley and Eſſington canal, and of the Staffordſhire and Worceſterſhire canal, all near Wolverhampton town; then by Taterhall, Wrotteſley, Blimhill, Cowley, Wooton, (near Eccleſhall), Broughton, Aſhley, Maer, Madeley-park, to Keeſe, (near Newcaſtle-under-line,) where it has again got upon coal-meaſures, by Bignole-hill, and acroſs the Harecaſtle tunnel, on the Trent and Merſey canal, by Golden-hill, Wickinſtone rocks, and, croſſing an immenſe fault, deſcends to the lime-ſtone ſhale, (ſee Mr. Farey's ſection in *Plate* II. vol. xxxi. of the Philoſophical Magazine,) on Biddulph Moor; thence paſſes the top of the Great Rudyard reſervoir, to Gun-hill, and croſſing to High Roches rocks, it there aſcends the firſt grit; then croſſes a ſmall trough of the firſt coal-ſhale and ſecond grit, and deſcends again to the firſt grit, or Ramſhaw rocks, and ſtill further, on the lime-ſtone ſhale, at the Royal Cottage, along which it proceeds to the N.W. ſide of Flaſh, and then aſcends the firſt grit again, on South-Axe-edge-hill; it again deſcends to the ſhale lime-ſtone in croſſing Middle and Great Axe-edge-hills; from whence it aſcends acroſs the firſt grit and firſt coal-ſhale, and aſcends the ſecond grit on Thatch Marſh; this it purſues to the north of the Macclesfield and Buxton road, and then turning N.E. again deſcends to the lime-ſtone ſhale, and follows it acroſs the Mancheſter and Buxton road; ſoon after, it aſcends the firſt grit and firſt coal-ſhale, on Comb's-moſs, and again deſcends to the ſhale, paſſes Sitting-low, (1½ mile S.E. of Chapel-en-le-Frith,) when, turning eaſtward, it croſſes the Great lime-ſtone fault, (N. of Dove-holes,) and is found upon the third lime-ſtone, on which it croſſes the quarries and rail-way of the Peak-Foreſt canal; ſoon after, it paſſes over the baſſet-edge of the third toad-ſtone, and deſcends to the great fourth lime-ſtone in Peak-Foreſt, which is probably the *loweſt* ſtratum, to which the grand ridge paſſes in its route through England; this lime-rock having been eſtimated to be four miles at leaſt of perpendicular thickneſs below the top of the chalk, from whence we commenced our deſcription; much the greater part of this vaſt ſeries of ſtrata having in this route along the grand ridge been loſt ſuddenly by perpendicular liſts of the ſtrata or faults, which, in proceeding to this point by more favourable routes, might have been ſeen baſſeting in ſucceſſion. For about one and a half mile the ridge proceeds upon the fourth lime, then again aſcends a point of the third toad-ſtone and third lime, to the village called Sparrow-pit, in the Mancheſter and Caſtleton road, where it again croſſes the great fault and aſcends to the lime-ſtone-ſhale on Ruſhop-edge, whence it proceeds northward, and after croſſing the Bridle-road from Hayfield to Edale-chapel, it aſcends the firſt grit on Edale rock, and proceeds acroſs the moſſes on Kinder-ſcout hills; theſe it leaves at their N. W. corner, and croſſes the moſſes on the ſhale, and the ancient Bridle-road called Doctor-Gate, from Gloſſop to Aſhop-Dale; it then aſcends the firſt grit again on ſhelf-ſtones, and follows the ſame to Wain-ſtones and Blakelow-ſtones, which ſeems to be the higheſt land in Derbyſhire, it then paſſes N. E. by Round-hill, and aſcends to the firſt coal-ſhale, croſſes the Mancheſter and Peniſtone-road at Lady-croſs; where, turning N. W. it aſcends the ſecond grit rock, and proceeds by Dean and Bretland Edges, to croſs the Gloſſop and Huddersfield road, on the bogs upon this rock on Holme moſs; from hence the ridge, after ſome diſtance, again deſcends to the firſt coal-ſhale, the firſt grit, and to the limeſtone-ſhale, croſſing the Stanage tunnel on the Huddersfield canal near Marſden; the ridge then proceeds acroſs Black-ſtone-edge, and croſſes the deep-cutting of the Rochdale canal, near the village of Hundersfield, (which has improperly been ſaid in the population accounts of 1801, to be a *town* containing 10,671 perſons!) the ridge then paſſes Holme on the Burnley and Halifax road, whence it proceeds, and near Colne comes again upon coal-meaſures, which are, however, loſt again at the great fault, in which part of the Foulridge tunnel on the Leeds and Liverpool canal was driven, and which occaſioned the extraordinary trouble and expence attending that tunnel, which is mentioned in our article Canal. From hence the grand ridge proceeds, by Barnoldſwick, Weſt Marton, near the Cold-Coniſtora, E. of Settleton lime-ſtone, over Pennigant-hill, Snays-fell, Nine-ſtandards, Kelton-fell, Lune-foreſt, Scordal-head, Milborn-foreſt, Aldſtone-moor, (lime,) Hartſide-croſs, Geltſdale-foreſt, Talkin, and croſſes the Roman or Picts wall on the E. ſide of Upper Denton, and ſoon after it enters Roxburghſhire in Scotland; through which it is much eaſier to trace this grand ridge than in England, it forming often the boundaries between the Scotch counties, to which this ridge and its collateral ridges are much better adapted than the rivers and brooks, which have generally been choſen as boundaries, both as being more permanent, and not liable to the changes which ſtreams of water are undergoing in the bottoms of vales, and avoiding thoſe diſputes reſpecting, and the delay of making and improving bridges, fords, navigations, mills, &c. owing to the rivers being part in one county and part in another, and by which alſo many of the moſt conſiderable towns are ſplit into two or more counties, to the no ſmall inconvenience of their inhabitants, in judicial and other county matters.

—Alfo, a river of Sicily, which runs into the Mediterranean on the N. fide of the ifland, N. lat. 38° 3'. E. long. 14° 54'. —Alfo, a river of America, which runs into the Miffouri, N. lat. 38° 56. W. long. 93° 25'.—Alfo, a broad river of America, which difcharges itfelf into lake Michigan, N. lat. 43° 25'. W. long. 85° 35'.—Alfo, a river of America, which runs into lake Erie, N. lat. 41° 55'. W. long. 81° 8'.—Alfo, a river of Canada, which runs into the Detroit, N. lat. 42° 34'. W. long. 82° 42'.—Alfo, a river of Canada, which runs into the St. Laurence, N. lat. 47° 3'.

GRAND *River*, or *Rio grande*, a river of Africa, which runs into the Atlantic, near the Biffagos ifles, N. lat. 11°. W. long. 14° 30'.

GRANDE *Seaux*, an Indian nation, inhabiting a territory of the Miffouri, and able to furnifh 800 warriors.

GRAND *Surry-Canal*. This canal is yet in the fame ftate, nearly, as when our account of it in the article CANAL was written, in 1805, except, that about two miles in length of it, at its N. E. end, has been brought into ufe, fince the Croydon canal has been completed; and that the dock for fhips, at its entrance from the Thames, was completed and opened in June 1807, and has anfwered fo well to the proprietors, that in the laft feffions of parliament, they made an unfuccefsful attempt to obtain power for a further extenfion of them. In February, 1809, this company determined on erecting a ten-horfe fteam engine on the banks of the canal, by the Deptford road, for fupplying the neighbouring inhabitants with water, intending to let the furplus power of this engine to fome manufacturers.

GRAND *Traverfe*, a range of iflands, confifting of huge rocks in lake Michigan.

GRAND *Trunk Canal*, is a name commonly applied to the Trent and Merfey canal, which fee in our article CANAL.

GRAND *Union Canal*. In the feffions of parliament, 1810, (50 Geo. III.) an act paffed for making the Grand Union canal, the general direction of which is about S.W. 23½ miles, in the counties of Leicefter and Northampton, being confiderably elevated, and croffing the grand ridge of the ifland twice, by tunnels, its middle part for about half its length fkirting near to the ridge on its weftern fide, and the two ends being on the eaftern fide of the ridge. Its objects are the completing of the long-defired water-communication between the Trent river and the many canals which connect therewith, in Derbyfhire, Nottinghamfhire, and Leicefterfhire, and the Grand Junction canal, and through it to the metropolis, without making the enormous circuit by Burton, Fradley-heath, near Litchfield, Tamworth, Atherftone, Nuneaton, and Braunftone, which at prefent goods, coming by water from Leicefter, Nottingham, and Derby muft do; it is intended alfo to fuperfede the neceffity for the fouthern part of the Leicefterfhire and Northamptonfhire Union canal, between Market-Harborough and Northampton, which on account of its difficulties has never been attempted; the prefent rail-way branch between the Grand Junction and Northampton is intended to be changed for a canal with locks, by which means the people of Northampton will have a water-communication with Market-Harborough, Leicefter, &c. with only about 14 miles longer diftance than the Leicefterfhire and Northampton Union would have been, if the fame had been completed according to its original act. Market-Harborough and Daventry are the only confiderable towns near the line of this canal, which commences in the Leicefterfhire and Northamptonfhire Union canal near Gumley, and terminates in the Grand Junction canal near Buckby-wharf, near the S. E. end of the Braunftone tunnel. From Gumley in ½ mile is a rife of 76 feet by 12 locks, and thence to Watford, 20 miles are level, then in ½ mile is a fall of 53 feet by eight locks, and thence to the Grand Junction canal about three miles are level; near Hufband's Bofworth is a tunnel of about 1120 yards long, and near Crick another of about 900 yards long. Near Crick it is propofed to make a refervoir of 60 acres above the canal, but below its level, fo that the furplus water collected from other parts of the canal in rainy feafons can be here referved, to be pumped up when wanted.

The width of the canal at top is 42 feet and 14 at bottom, and its depth of wa er five feet; the locks are 82 feet long and feven wide, calculated for 25 ton boats. This line was firft furveyed by Mr. James Barnes in 1803, and by Mr. Benjamin Bevan in 1808 and 1809, and the latter is appointed engineer for the execution of the work.

GRAND *Weftern Canal*, is fo denominated in an act which paffed in the year 1796, as mentioned in our article CANAL, but under which no progrefs had then been made. In April 1810, it was reported, that a beginning had at length been made on the fummit level, in Holcomb, Devon. A much larger canal, capable of conveying fhips from the Briftol channel to the fouth coaft, has been fome time in agitation, for avoiding the very circuitous and tedious navigation round the Land's End; which, however defirable, is fcarcely practicable, we incline to think, for want of water.

Graver

GRAVER, a ſteel inſtrument, ſerving to engrave on metals. The graver conſiſts of four ſides or faces, and the point uſually terminates in a lozenge: in ſome it is round, and in others ſquare. The round point is beſt for ſcoring lines, the ſquare for cutting broad and deep, and the lozenge for more delicate and fine ſtrokes and ſcratches. Le Boſſe recommends thoſe of a form betwixt the ſquare and lozenge. See Engraving.

The gravers ſhould be made of the beſt ſteel, which muſt be drawn out into ſmall rods with a charcoal fire. Theſe rods, after having been cut into the proper lengths for gravers, ſhould be ſoftened, by heating them in a charcoal fire, and ſuffering them to cool very ſlowly: let them next be filed into the deſired form, and brought back to a hard temper by heating them red-hot, and in this ſtate dipping their ends into ſoft ſoap. This ſhould be done in a perpendicular direction; for, if they be turned in the leaſt degree obliquely, the graver will warp and be crooked. If the temper of the graver be too hard after this treatment, and prevent the whetting it properly to an edge, it may be ſoftened, by laying its end on a large burning piece of charcoal till it begins to grow yellow, and then thruſting it into a lump of tallow, or dipping it in water; but if water be uſed, the graver muſt not be too hot. It may be known whether the graver be tempered to a proper hardneſs by touching the edge of it with a file, which, if any effect attends it, proves the temper to be too ſoft. The beſt proof of too great hardneſs is the breaking of the point in engraving; after which, if a new edge be made by whetting the graver, it will be frequently found very good without any other alteration. Handmaid to the Arts, vol. ii. p. 56.

The other end is fitted into a wooden handle.

Beſides engravers, the ſeal-cutters, lock-ſmiths, gun-ſmiths, gold-ſmiths, armourers, ſpurriers, &c. likewiſe make uſe of gravers.

Green

Green, one of the original colours of the rays of light. Grafs and herbs, and even all vegetables in places expofed to the open air, are green; and thofe in fubterraneous places, or places inacceffible to the air, white and yellow. Thus when wheat or the like germinates under-ground it is white or yellow; and when it is in the open air, green; though this too is yellow before it be green.

Greens, *Artificial*, are very rarely fimple colours, but produced by mixture of yellow and blue.

Two powders, the one blue, and the other yellow, well mixed, appear perfectly green; though, when viewed with a microfcope, we obferve a chequer of blue and yellow.

The tincture of red rofes with oil of tartar per deliquium, or with fpirit of fal ammoniac, produces green. The tincture of many red flowers is changed into green by an alkali. The tincture of red rofes, and the yellow tincture of crocus, or the blue tincture of cyanus, and the white fpirit of fal ammoniac, produce green. The folution of verdigris becomes colourlefs by the affufion of the fpirit of nitre, and by the affufion of the oil of tartar it becomes green again.

As no vegetable has yet been difcovered, which is capable of giving to cloth of any kind a permanent green colour, the dye for this purpofe is a compound colour, formed in dye-vats either by putting a yellow on a blue ground, or a blue on the yellow ground, or by mixing the blue and yellow materials, and dyeing with them as with a fimple colour. The common and moft permanent green is given to woollen cloth in the following manner. The cloth, being firft dyed blue in the indigo vat (fee Indigo), is then well fcoured, and afterwards dyed in a bath of weld or any other yellow dye with alum and tartar, as in the mode of dyeing of fimple yellows, except that the yellow materials are ufed in greater quantity than the yellow alone of equal body would require. Very deep greens are made to acquire a flight brown or kind of burnifh by adding to the bath fmall quantities of logwood and fulphat of iron. As for filks, they are firft ftrongly alumed, then dyed yellow with weld, and afterwards finifhed in the indigo vat. Silk, cotton, and linen are dyed green in the fame general mode, but with confiderable variations in the different proceffes. The moft beautiful green hitherto known, and which perfectly well refifts the action of light and air, is given by the combination of Pruffian blue and yellow, but this colour is deftroyed by foap and alkalies. To cotton this colour is given, by firft dyeing it olive with weld, or any other yellow dye, and a compound mordant of alum and iron, and then raifing the green by pruffiat of potafh. (See Prussian *blue*.) Berthollet obferves, that in the procefs for this purpofe there feems to be a mutual diftribution of the mordants and colours, the Pruffian colour taking the iron and becoming blue, whilft the alum and weld remaining in the olive form a faft yellow, and unite with the blue into a fine green. The only fimple green in common ufe is that of the carbonated oxyd of copper precipitated from verdigris by an alkali. A folution of verdigris is made in vinegar, and a few hours before dyeing a folution of as much pearlafh as verdigris is added to it, the mixture is heated, and the cotton, previoufly alumed, is paffed through this bath. The colour then given is a foft apple-green. Aikin's Dict.

The dyers make divers fhades, or cafts of green, as *light* green, *yellow* green, *grafs* green, *laurel* green, *fea* green, *dark* green, *parrot* green, and *celadon* green.

Green, *Brunfwick*, is a pigment ufed by fome of the German artifts, which they prepare by adding to the faturated folution of one part of muriated ammonia in cold water, three parts of copper clippings; and by covering the glafs veffel that contains it with gaufe fo as to keep out the duft, and placing it in a warm fituation, fo that the moifture may evaporate, which purpofe will be effected in a few days. The muriat of ammonia foon begins to be decompofed by the copper, which is corroded and converted into a green oxyd. When the whole is evaporated to drynefs, let it be digefted in two or three fucceffive portions of fpirit of wine, as long as any green oxyd is taken up; then add the folutions together and expel the liquor by a gentle heat, the refidue is a pure dark green fub-muriat of copper, known in the fhops by the name of refined Brunfwick green.

Green, *Mountain*, or *Hungary green*, is a fort of greenifh powder found in little grains, like fand, among the mountains of Kernaufent in Hungary, and thofe of Moldavia. Though fome hold, that this mountain green is factitious, and the fame with that the ancients called *flos æris*, prepared by cafting water, or rather wine, on copper red-hot from the furnace, and catching the fumes thereof on copper plates laid over for that purpofe: or by diffolving copper-plates in wine, much as in making verdigris. The painters make ufe of this colour for *grafs* green. It is fometimes counterfeited by grinding verdigris with cerufs.

Green, *Calcined*, and *diftilled green*. See Verdigris.

Green, *Pruffian*. See the procefs for making Prussian *blue*.

Green, *Sap*. See *colours from* Fruits, Buckthorn, and Sap-*green*.

Green, *Saxon*, an extremely beautiful green colour, fo called becaufe the blue part is given by the Saxon blue or fulphat of indigo; the procefs of dyeing which is this; the cloth or filk is firft to be dyed a Saxon blue, in the following manner. Having ground nine parts of indigo with twenty of red arfenic into a fine powder, add forty-eight parts of ftrong fpirit of vitriol; which mixture fwells, grows hot, and emits a fulphureous fmell. After ftanding in a moderate warmth of twenty-four hours, pour off the liquid part, which will be of an extremely deep blue. A fmall quantity of this liquor, dropt into hot water, inftantly fpreads, tinges it of a fine light blue, and fits it for dyeing

the prepared wool, cloth, or silk; and by increasing or diminishing the proportion of the blue composition, the colour may be rendered deeper or lighter. This, Dr. Lewis says, is the method used for preparing the blue composition by the dyers of Norwich, who purchased this secret from Saxony.

The cloth or silk, thus dyed blue, is next alumed, and then dipped in the yellow decoction of weld or fustic, and the desired colour will be obtained.

Fustic is commonly preferred as the yellow material, because it is less liable to be altered by the adhering acid of the sulphat of indigo than weld or the other yellows. To correct this effect of the acid, and enable quercitron to equal the fustic in this respect, (whilst its natural colour much excels it,) Dr. Bancroft advises, after the cloth has received the blue, to mix chalk with the alum mordant, in order to neutralize the adhering acid, before the yellow is given.

Or the subject may be dyed green at one operation, by boiling it for a little time in a mixture of the blue and yellow liquors. For this purpose the cloth is first alumed and well rinsed; and the cloth is then dyed in a strong decoction of fustic, to which, when cooled to a blood heat, is added sulphat of indigo. Dr. Bancroft recommends for dyeing a beautiful Saxon green, the following expeditious process, by using the compound alum and tin mordant; put into the boiler six or eight pounds of quercitron bark to every one hundred pounds of cloth; boil with a sufficient quantity of water; then add six pounds of the murio-sulphat of tin, (in preference to the nitro-muriat,) and four pounds of alum: when these have boiled five or six minutes, lower the heat with cold water to blood-warm, after which, add as much sulphat of indigo as may be thought necessary for the intended depth of colour, and then dye the cloth in this bath with proper care. Aikin's Dict.

By combining any blue and yellow dyes, in different proportions, all the shades of green may be produced, from the blueish green of the cabbage-leaf to the greenish-yellow of the olive.

Greenock

GREENOCK, the principal sea-port town on the firth of Clyde, situated on the south bank of the river, about 24 miles below the city of Glasgow. The town of Greenock is pretty well situated for commercial purposes, but in other respects it is neither pleasant nor so circumstanced as to afford the prospect of any great increase either of extent or population. Indeed the great number of young men, who, from habits of imitation as in other sea port towns, early attach themselves to a seafaring life, must present of itself a great obstacle to the latter. The town of Greenock is held under and is entirely surrounded by the lands of sir John Stewart of Blackhall, bart., who is feudal superior, and no purchase or acquisition of ground, either for the purposes of extension or improvement, can be had from any other person. This must of itself render extension a matter of more difficulty than where there are many landed proprietors, the lands of some of whom, from the common casualties and vicissitudes of human affairs, must be occasionally in the market.

The harbour of Greenock is divided into two compartments, and is entirely surrounded by well-built and commodious quays of freestone. The entrance is narrow, and in the centre opposite to the end of the mid quay, which serves as the division of the harbours. The eastern harbour is shallow, and is therefore mostly frequented by coasting vessels, herring busses, fishing boats, and other small craft. The west harbour, being considerably deeper, is the general resort of West Indiamen, American traders, and other vessels of greater burthen. In the west harbour is a very capital dry or graving dock, with flood gates to exclude the water, and capable of containing two large ships at the same time. It has been long in contemplation to improve the harbour of Greenock by the erection of wet docks, similar to those of London, Liverpool, Hull, and Leith, but probably from the difficulty of engaging the joint consent of the numerous interests concerned, and other causes, no steps have been hitherto taken for carrying this scheme into effect. The principal deficiency of the harbour of Greenock, exclusive of the ships bottoms taking the ground every ebb tide, arises from want of water, there being never more than seventeen or eighteen feet in the harbour, even at spring tides. Hence large vessels are obliged to discharge part of their cargoes into lighters in the roads before they can come into the harbour at all. This is of less consequence where the cargo is to be brought to Glasgow, if the weather be mild, but it is very inconvenient and expensive when the cargo is to be landed, and, when the weather is boisterous. The whole rise of the tide at Greenock is only about twelve feet, whereas at Liverpool it is thirty-six and at Bristol forty-two. This also forms an additional disadvantage to the harbour of Greenock, and presents a very great obstacle to every plan of artificial improvement. With all these disadvantages, however, it has many advantages over the neighbouring harbour of port Glasgow, situated about three miles farther up the river. The chief obstacle to vessels of great burthen making any of these ports, is an immense bank of sand, accumulated for many ages in this *embouchure* of the Clyde by the current of the river, and which is sensibly though slowly increasing. Indeed nearly opposite to port Glasgow, this bank is entirely uncovered for miles at low water. Notwithstanding these natural disadvantages, the favourable situation of the Clyde for maritime intercourse with every part of the western hemisphere and the south of Europe, the great coasting trade with the western parts of England and Wales, and with Ireland, and the extensive herring fishery, has raised Greenock to a high rank among the commercial ports of Britain, and has been productive of the acquisition of splendid fortunes to many of the principal inhabitants. As Greenock is not the seat of any staple manufactory, this carrying trade is her chief, and indeed may be fairly called her only support. During the American war, when the carrying trade was entirely suspended in some channels, and greatly impeded in all the others, a number of ship-owners fitted out their vessels as privateers, but in general these speculations were not productive of gain to the adventurers, and in some instances with serious loss. In the recent wars no attempts at privateering have been made.

The town of Greenock is governed by two magistrates, elected annually, and a council; besides whom, the baron baillie, nominated by the superior, also possesses a jurisdiction. The sheriff court of the county of Renfrew is held at Paisley, to which the inhabitants of Greenock are amenable, the same as the rest of the county.

In the external appearance of Greenock there is little elegance or splendour to be seen. In the centre of the town there is a small square, immediately fronting the mid-quay, which divides the harbour. In this square is a very handsome church of modern architecture. The other buildings are the inns, of which the chief, recently built upon a tontine scheme, like that of Glasgow, is a very spacious, and even splendid house. There is also a small neat theatre, the private property of Mr. Stephen Kemble, the manager, and some dancing-halls for the occasional recreation of the inhabitants and strangers, of whom, from the maritime situation, there is, at certain seasons, particularly at the arrivals of the West India fleets, a considerable influx.

The scenery of the Clyde around Greenock is picturesque and sublime. The river is about seven miles broad to the opposite shore, where the village of Helensburg is erected upon the property of sir James Colquhoun of Luss, bart. This village is built in a very pleasant situation, upon a fine bay,

formed by two projecting promontories, *viz.* by the hill of Ardmore, on the eaft, and by Rofeneath, the property, and one of the fplendid refidences of the duke of Argyle, on the weft. Beyond this, to the weftward, appear the lowering mountains of Argylefhire, between which is the vaft arm of the fea, Lochlong, which is twenty-four miles in length, and in fome places faid to be unfathomably deep. About two miles to the weft is a fmall village, called Gourock, fituated on a very fine deep bay, well fheltered by projecting head-lands, with a very good bottom for anchorage. It is the opinion of moft profeffional men, whether engineers or feamen, that this fituation affords by far the greateft number of natural advantages for a large and commodious fea-port upon the Clyde; and it is almoft fingular that Greenock fhould have rifen to its prefent commercial importance, whilft Gourock, fituated within lefs than two miles, and poffeffing every fuperiority of phyfical advantage, fhould have remained an infignificant village. However this may have originated, too much capital has now been expended upon Greenock and Port Glafgow, to leave the fmalleft room to fuppofe that they will be in any refpect rivalled by a village which poffeffes nothing but natural fituation to recommend it. On the road from Greenock to Gourock are many very fine villas, belonging to the opulent merchants of Greenock. At both Greenock and Gourock are extenfive rope-works, belonging to the fame company of proprietors. A little below Gourock is the Clough light-houfe, a very high and well-built tower, lighted by reflectors, for the fafety of veffels coming up, or going down the channel during the night. Some miles below this is the ifland of Bute, belonging chiefly to the nobleman to whom it gives the title of marquis. Bute is about feven miles long, and generally level and fertile. Mount-ftewart-caftle, the refidence of the noble proprietor, is fituated near the middle of the ifland, on the fouth fide, and is a fuperb and delightful place. Of the other proprietors, lord Bannatine, one of the Scottifh judges, is the moft confpicuous. The chief, and, indeed, almoft only town on the ifland, is Rothfay, from which his royal highnefs the prince of Wales derives one of his Scottifh titles, is a handfome, clean, fmall town, and has a confiderable cotton mill and manufactory by it, belonging to a company of manufacturers in Glafgow. There are alfo the ruins of an old caftle, which appears to have been of great extent, and once belonged to the royal family of Scotland. The inhabitants of Rothfay are chiefly fea-faring people, and employ themfelves much in the herring fifhery during the feafon. Large quantities of fine cod-fifh are alfo caught off the coafts of Bute, Arran, and Argylefhire, with which the markets of the weft of Scotland are fupplied, generally at a rate not exceeding two-pence *per* pound of 22½ ounces. Contiguous to Bute is a fmall ifland, called Inch Marnock, which is level and cultivated. It is the refidence only of thofe employed in its cultivation. The ifland of Arran is nearly thirty miles in length, and is very mountainous. The higheft hill, called Goatfield, is feen from a great diftance. The ifland of Arran is the property of the duke of Hamilton, who is earl of Arran, who has a fine houfe, called Brodick caftle, on the ifland, where his family fometimes refide, efpecially during the feafon for fhooting groufe or black game. Arran ufed to be much noted for a fmuggling trade, both in contraband articles brought by the feamen employed in the veffels trading to the Clyde, and alfo in the diftillation of whifky. The vigilance of the revenue cruifers in the Clyde has, in a great meafure, checked the former, and that of the excife officers the latter. On Arran are found a number of fine ftones, and it is fometimes vifited by lapidaries, during the fummer, for the purpofe of fearching for them, or of purchafing thofe occafionally picked up by the natives. On the ifland are only two fmall towns or villages, *viz.* Brodick and Lamlafh, the latter of which, being defended from the fouth winds by an ifland in the mouth of the bay, is reforted to as a fhelter in ftormy weather by the fhips and veffels navigating the frith of Clyde.

Befides thofe already mentioned, there are a few fmaller iflands in the frith, *viz.* the Cumbraes, which are two fmall iflands lying pretty clofe to the fouthern fhore, near the Renfrewfhire coaft, oppofite to the village of Largs, about 16 miles below Greenock. The larger ifland is about two miles long, and on it is a very neat village, called Milport, chiefly inhabited by fifhermen and feamen's families. The leffer ifland is a mere rock, where a few perfons refide, who take charge of the light-houfe, and fometimes perfons in a ftate of infanity are boarded here by their relatives, on account of the purity of the air, and the retirement of the fituation. Farther down, and near the Ayrfhire coaft, is the ftupendous rock, or crag of Ailfa, from which the proprietor, the earl of Caffius, derives his Britifh title. Ailfa is a high abrupt and barren rock, totally uninhabited, and covered by myriads of fea-fowl, in fearch of which it is fometimes vifited. Of the general trade of the Clyde notice has already been taken under the article GLASGOW.

Grind-mill

GRIND-MILL, or *Blade-mill*, in the *Manufactures*, is a kind of mill common in the neighbourhood of Sheffield, and other places where cutlery, edge-tools, and polished steel articles, as fenders, &c. are manufactured: in these mills, a great number of large grind-stones are mounted on spindles, and, by means of straps, are turned with great velocity. Water, in all the rivers and brooks near Sheffield, was formerly applied to these mills, but of late years several large steam-engines have been applied, to work additional grind-mills in the town and neighbourhood: the first of which was erected by the late Mr. Francis Thompson, engineer, of Ashover, Derbyshire. See CUTLERY.

GRIND-STONE, *cos gyratalis*, in *Natural History*, is a very coarse, rugged, rough, and harsh stone, of a yellowish brown colour, composed of an irregular grit, cemented together by a coarse and debased terrene crystalline matter, and intermixed with a very few glittering spangles of white talc; it cuts freely, but bears no polish; it is pervaded by water, will not strike fire with steel, is not acted upon by acids, and burns to a deep red colour, but acquires no hardness. It is chiefly dug in the northern counties of England, and used for grind-stones, whence its name.

GRIND-STONES, in the *Manufactures*, are flat circular stones used for the grinding of edge tools, when such are mounted on a spindle, and turned by a winch-handle, as is common in every part of the country; but in districts where cutlery and tools are manufactured, great numbers of these stones are used in one building, called a grind-mill or blade-mill, and are turned by water or steam-engines. (See GRIND-MILL.) The stone suited to form grind-stones is what is denominated a sharp grit, that is, the grains of sand or silex of which it is composed are partly uniform in size, and are firmly attached to each other by a silicious or other very hard cement, without the interstices between the grains being filled up, as frequently is the case, or nearly so, with the other kinds of sand-stone. Grind-stones are of very different degrees of fineness, in the grains of silex, according to the different strata whence they are obtained: the coarsest and best for heavy works, such as the grinding of gun-barrels, &c. are from the first or mill-stone grit of the Derbyshire strata (see the section of these, in the Phil. Mag. plate 2, vol. xxxi.): others are from the third rock, the next stratum but two above the former: and in other counties coarse grind-stones are manufactured from the coarse grit rocks near the bottom of their different coal series; for it is rather remarkable, that all the grind-stone quarries with which we are acquainted, are in the coal-measures or strata where vegetable remains abound. The finer sorts of grind-stones, and what are called whitening or polishing stones by the Sheffield cutlers, are from *different* rocks, in the upper part of the great Derbyshire coal-series; Mr. Whitehurst, p. 168. of his "Inquiry," seems to have known, or distinguished but two out of the 18 or 20 grit-stone rocks which this series contains, and says, "the *upper* stratum of argillaceous stone is excellent for the use of cutlers' grinding-stones." Mr. Mawe's knowledge of these strata seems to have been equally confined, see his section and description in the "Mineralogy of Derbyshire," p. 14. It may prove interesting to many of our readers, to see the following list of grind-stone quarries, with their degrees of coarseness, *viz.*

Ashover, N.W. (hill quarry) Derbyshire, middling.
Ayreshire (water of Ayre) Scotland.
Beely Moor, E. of the town, Derbyshire, coarse.
Belper, S.E. (Hungerhill) Derbyshire, middling.
Biddulph-Hall, N.W. of Leek, Staffordshire, coarse.
Bilstone, S.E. of Wolverhampton, Staffordshire, middling.
Bolsover, N.W. (nunnery) Derbyshire, middling.
Bredsal Moor, N. of Derby, middling.
Brinclif-edge, S.E. of Sheffield, Yorkshire, fine.
Buxton, N. (Corbar) Derbyshire, fine.
Darley Moor, E. of the town, Derbyshire, coarse.
Gate-head fell, S. of Newcastle, Durham.
Glossop, Derbyshire, coarse.
Harthill, S.E. Yorkshire, fine.
Hooton-Roberts, near Rotherham, York, middling.
Horsley, N. of Derby, fine.
Lane-top, N. of Sheffield. Yorkshire, whitening.
Little-Eaton, N. of Derby, coarse.
Milford, S. of Belper, Derbyshire, coarse.
Molecopt-hill, S. of Congleton, Cheshire, coarse.
Morley-Moor, N. of Derby, fine.
Norton, W. (Hemp-yard lane) Derbyshire, fine.
Overton (Gregory) in Ashover, Derbyshire, coarse.
Polesworth, S.E. of Tamworth, Warwick.
Purton, W. of Wolverhampton, Staffordshire, fine.
Ridgeway (Lum-delph) in Eckington, Derbyshire, fine.
Stanley, N.E. of Derby, fine.
Stanton by Dale, E. of Derbyshire, fine.
Stanton Moor, N.E. of Winster, Derbyshire, coarse.
Therberg, near Rotherham, Yorkshire, fine.
Treton ditto. ditto. fine.
Warton, E. of Tamworth, Warwickshire.
Wickersley, near Rotherham, Yorkshire, middling.
Wokes, near Barnsley, Yorkshire.

Some of these quarries are very ancient; that in Ashover is noticed in the Doomsday survey, but since the inclosure of the parish it has been disused. The sale of grind-stones

from some of them, where navigations are near, are very considerable.

GRINDERS, MOLARES *dentes*. See *Molares* under the article CRANIUM.

GRINDING, TRITURATION, the act of breaking or comminuting a solid body, and reducing it into powder, dust, flour, farina, or the like.

Grinding is one of the species of dissolution. The painters' colours are ground on a marble or porphyry, either with oil or gum-water.

Some late physicians contend, that digestion is performed by grinding the food in the stomach. See DIGESTION.

GRINDING is also used for rubbing or wearing off the irregular or otherwise redundant parts of the surface of a body, and reducing it to the destined figure, whether that be flat, concave, or the like.

The *grinding of glasses* is a considerable art, and, as such, necessarily requires to be here insisted on; especially that of optic glasses.

Method of grinding optic-glasses.—For convex glasses, the first object is to provide a dish or bason, within whose cavity the glass is to be formed.

In order to this, they take a piece of brass, copper, iron, or wood, and form it into a segment of a circle, having the radius of the bason or the dish intended: this done, a bason is forged by a smith, either of iron or copper, having its cavity exactly fitting or corresponding to the segment above mentioned, though sometimes they chuse to have the bason cast; in this case, the rules elsewhere delivered for concave mirrors are to be here observed. (See MIRROR.) The figure of the bason, thus roughly formed, is to be finished in the pewterer's lathe, or on a stone mould A, *Plate* V. *Optics*, *fig.* 3, fixed to an iron axis with a pinion B C, moveable by a wheel D E, and that by a winch or handle F. The bason being ground on the mould till it exactly fits in all parts, they take it off, and cementing it to a wooden block (loaden, if need be, with lead), strew it over with fine sifted sand, and thus grind it over again on the mould, till all the furrows or scratches be quite taken away.

Lastly, they grind large pieces of glass in a bason, with find sand between, till such time as, its surface being well smoothed, there is no longer any opposition to the motion.

Note, the dish is known to be perfectly finished when, a hair being stretched over it, its shadow projected in the cavity, especially in a camera obscura, does not appear any way distorted.

The bason finished, they proceed to choose glasses for the purpose: in order to this, lay them on clean paper, and observe what colours are projected upon it; for the same are the colours of the glasses. Always set aside those of the darker colours, and choose the brighter; but as the whitest and brightest have usually veins, and besides, in tract of time, by the humidity of the air, are apt to rust and lose their polish; for this reason Huygens recommends those a little yellowish, reddish, or greenish; Hevelius the blueish. A glass is found to be free from bubbles, sands, veins, knots, and spires, by holding it to the sun, and receiving the rays through it on a white paper; for the flaws above mentioned will each project a shadow upon it.

If, instead of lenticular, or at least spherical glasses, you make use of plate-glass, it must be divided and cut with a diamond into squares; and if it be too thick to break otherwise, you may do it by laying it on a table covered with cloth, in such manner as that the side or part to be severed hang over the edge: for, being struck with an iron instrument, in this situation, it easily breaks in the direction of the line drawn by the diamond. Having thus got a square piece, describe two concentric circles upon it with a pair of compasses, one of whose legs carries a diamond: the diameter of the inner circle to be equal to the breadth of the intended lens, and that of the outer somewhat more; and break off the corners, as above directed, and the lesser inequalities take off on a grind-stone, or the like. Examine now whether the piece of glass be every where equally thick; if it be not, reduce it to such equality by grinding it on an iron plate with sand and water. Lastly, glue or cement the glass thus prepared to a wooden handle N M O, *fig.* 4. with a cement made of pitch and a fourth part of resin, or one part of wax and eleven of colophony: care being taken that the base or bottom of the handle N O be equal to the glass, and that the centre of the glass and handle meet together. Smaller lenses, as those used for microscopes, are fixed on with sealing-wax.

Now, to grind the glass, and bring it to the convexity required, smear over the dish equally with fine sifted sand moistened with water; then taking the handle with the glass on it, work it on the bason, sometimes this way, and sometimes that, to prevent the form of the bason from being disturbed, never leaning too hard upon it. When the glass has got the figure of the bason, clean it well of all the sand and filth adhering, and sprinkle the bason over with emery moistened in water, grinding the glass thereon till all the roughness and inequalities are taken away: after this, the fine sand used in hour-glasses may be of service, applied and used as before; remembering to take out the sand, when too much worn, and substitute new in its stead. Some, in lieu of this, choose several sorts of emery, each finer than the other, or even the power of flint calcined and pounded. Lastly, grind the same glass in another bason or dish, which is a segment of a lesser sphere, making use of the like sand as before, till it has got a pretty high rim or margin all around. Because the pression is not here determined accurately enough upon the middle of the glass, by the mere guidance of the hand, some have chosen to make use of the following machine, especially for grinding object-glasses.

Fix the dish H I, *fig.* 5. on a horizontal table; exactly over its centre let the aperture D be, through which pass an iron arm five or six inches long, fastened to the staff A B: let the other extreme of the staff be fitted into a hole cut in the dish, and fastened therein. Now to grind the glass instead of the dish, take hold of the said staff, and work with sand, &c. as before.

Huygens tells us, that he always used first a coarse emery, then a finer powder of the same, which would be fifty seconds in sinking to the bottom of a vessel of water, putting in fresh every half or quarter of an hour: sometimes too, he used emery of fifty seconds, for three quarters of an hour; then emery of four hundred seconds, for four-fifths of an hour; and lastly, emery of forty-five minutes, for a quarter of an hour. The same effect is had from powder of flints, broken in an iron mortar, mixed with water, and stirred sometimes with a wooden spatula, taking the powder as it precipitates in some certain time to the bottom of the vessel, by decanting the water. What remains is to polish the glass.

For a more particular account of the method of grinding and polishing glasses for telescopes, extracted from Mr. Huygens and other authors, by Mr. Molyneux, and comprehending the method of making and polishing the tools, of choosing the glass, of preparing the glasses before they can be ground and polished, of grinding the glasses, and of

giving them the laſt and fineſt poliſh, we muſt refer to Smith's Optics, book iii. chap. i. paſſim.

The late ingenious Mr. James Short, in a paper left with the Royal Society, to be opened and printed after his death, gives the following directions for working object-glaſſes of refracting teleſcopes truly ſpherical.

Prepare two plates or tools, of braſs, the one convex, and the other concave, being both portions of a ſphere of the ſame radius as the focal length of the object-glaſs you want to have, or rather of a radius ſomewhat longer than the focal length you want, for a dioptrical reaſon; let theſe plates or tools be between two and three times the breadth of the object-glaſs deſired; or, in long focal lengths, twice the breadth will be ſufficient: let theſe tools be of a ſufficient thickneſs in proportion to their breadth or diameter, and let them be ground with fine emery exactly true to one another, working them alternately, the one above the other, to preſerve the ſame focal length; or, if it is deſired longer, you muſt work the convex above the concave; or, if deſired ſhorter, you muſt grind the concave above the convex.

After this, you prepare another braſs plate or tool, of the ſame breadth and thickneſs as the two former, and of the ſame radius of concavity: its being truly turned on a lathe will be ſufficient for this purpoſe; which tool is to ſerve afterwards for the poliſhing of the two ſurfaces of your object-glaſs, and therefore called the poliſhing tool.

Prepare a piece of ſtraw-coloured glaſs, of the plate-glaſs kind, of the proper diameter for the object-glaſs you deſire, which ought always to be broader than the proper aperture for that length; let this piece of glaſs be ground flat, in another tool, on both ſides and as nearly parallel as may be, and ſomewhat poliſhed, in order to diſcover whether there are any veins or flaws in the glaſs. When you are ſatisfied of the goodneſs of the glaſs, you are then to prepare a handle to faſten your glaſs to. Great care muſt be taken in this, for fear of bending your glaſs by the handle: Mr. Short adviſes to take a flat piece of braſs, or rather of the concavity of the ſphere, to which the glaſs is to be ground; this piece of braſs ſhould not be thicker than two-thirds of the thickneſs of the glaſs, of a circular form, leſs in breadth ſomewhat than the glaſs itſelf, and having ſides of the ſame form, at right angles to the flat piece of braſs, and theſe ſides ought to be of ſuch a ſhape as that the fingers may eaſily apply to it in working, and theſe ſides ſhould be as low as may conveniently be, and no thicker than about two-thirds of the glaſs. This handle is to be faſtened to the glaſs, by warming the glaſs and handle gently before a fire, and laying ſome pitch upon the glaſs thus warmed, till it becomes ſoft like melted wax; and then laying your braſs handle, a little heated, on the pitch, you preſs it a little, till you are ſure there is nothing between the glaſs and the handle but pitch; you then lay down the glaſs and handle upon ſomething flat, taking care that the handle is in the middle of the glaſs till it is entirely cold. It is very material to know, that the pitch, to be uſed for faſtening the handle to the glaſs, muſt be ſoft pitch, that has never been uſed nor melted; for any other pitch will infallibly bend the glaſs.

You then grind your glaſs in the concave tool with emery, and give it the proper figure and ſmoothing for the laſt poliſh, in the common manner.

In order to give your glaſs the laſt poliſh, which is the moſt difficult part of the whole work, you are to prepare ſome pitch for covering the before-mentioned poliſhing concave tool, which is done in this manner: take ſome pitch, and melt it in an iron ladle, and let it boil for a quarter of an hour or thereabouts; by this boiling, the pitch, when cold, will become hard and brittle: or you may ſhorten this operation, by melting equal quantities of pitch and roſin, and then there is no occaſion to let it boil ſo long. Your pitch being thus prepared, you again melt it, and take it off the fire, and let it ſtand till the pitch becomes pretty cold, or of a thickiſh conſiſtence; and having warmed the poliſhing tool a little, to make the pitch ſtick to it, you pour out of the ladle upon the poliſhing tool as much pitch as you judge will cover the whole tool, when ſpread out, to about the thickneſs of one-eighth of an inch; you then invert this tool with the pitch upon it, and preſs it upon the convex tool, which muſt be quite dry, clean, and cold, in order to give it the figure of the convex tool: in caſe it has not ſpread out ſo as to cover the whole ſurface of the poliſhing tool, you may warm the pitch by holding it before the fire, and preſſing it upon the convex tool, as before, till it has entirely covered the ſurface of the poliſhing tool; you then plunge it into cold water, till the braſs is quite cold.

N. B. In order to know if your pitch is hard enough, you preſs the edge of the nail of your thumb upon it, and if it receives an impreſſion, the pitch is not hard enough.

You then proceed to prepare this poliſhing tool, for the laſt poliſh of your glaſs, by grindi g this poliſhing tool upon the convex tool with pretty coarſe emery, and a ſmall quantity of water, in the common way that tools are ground one upon another; but this muſt be done only for a ſmall ſpace of time, and the poliſhing tool muſt have no other preſſure than its own weight, for fear of ſome of the emery ſticking in the pitch, and you muſt never allow the emery to grow dry: when you have ground the pitch, ſo as to be all over of the ſame colour, you then waſh the pitch from all the emery with a bruſh and clean water; after this, you take a bottle of water, and, holding the pitch tool in a ſloping poſition, you pour water out of the bottle ſo as to fall upon every part of its ſurface.

You then place the poliſhing tool in a horizontal poſition, and you put upon it ſome putty, waſhed from all its gritty particles, but it need not be the fineſt waſhed, and you put a good deal of water upon your poliſhing tool, mixing the putty and it together, and you poliſh your glaſs upon this pitch-poliſher in the common manner of poliſhing glaſſes.

After you have poliſhed your glaſs about ten minutes, you again grind your poliſher upon the convex tool with emery, as before, for fear the pitch has, by working, loſt any of its proper figure; and the oftener you do this, the truer will be the figures of your glaſs; and in this manner you proceed till the glaſs is quite poliſhed.

You then take your glaſs off its handle, by holding it before the fire, till it is ſo warm that you can ſlide the handle off the glaſs; and whilſt the glaſs is warm, you take off as much of the pitch as you can with the ſharp edge of a knife; you then lay the glaſs down to cool, and when quite cold, you drop ſome ſpirits of wine upon it; and this, with a cloth, will wipe off the reſt of the pitch.

You then examine the centre of the ſurfaces of your glaſs; and if it lies to one ſide of the centre of your glaſs, mark that place with a ſpot of ink, and then put on your handle as before, upon the ſide that is now poliſhed, with its centre over the ſpot of ink, and grind your glaſs as before, till the circular remaining part of the glaſs to be ground is as much diſtant from the centre of the glaſs on the other ſide from the ſpot as the ſpot was from the centre of your glaſs; you then, by heat, return your handle to the centre of the glaſs, and proceed to grind and poliſh this ſide of the glaſs as before.

N. B. The concave and convex tools ſhould be ground with fine emery, after you have done one ſide of your glaſs;

for the oftener thefe are ground together, you will be the more fure of having your figure true. Phil. Tranf. vol. lviii. p. 507, &c.

Method of Grinding, &c. the fpecula of reflecting telefcopes.—The method generally followed by workmen is that propofed by Meffrs. Molyneux and Hadley, and publifhed in Dr. Smith's Optics; this has been lately improved, in a very confiderable degree, by Mr. Mudge, whofe directions, founded on accurate experiments, and practifed with fuccefs in the conftruction of telefcopes, we fhall adopt wherever they differ from thofe that occur in the book juft cited. For making the gages, take a long pole of fir, deal, or any wood, of a little more than double the length of the inftrument intended, and ftrike through each end of it two fmall fteel points, and by one of them hang it up perpendicularly againft a wall; then take two pieces of thin plate-brafs, well hammered, a little thicker than a fixpence, which may be about an inch and a half broad, and let their length be in proportion to the diameter of the fpeculum as three to two; fo that if the fpeculum be eight inches diameter, thefe may be about twelve. Fix each of thefe ftrongly with rivets between two thin pieces of wainfcot, fo that a little more than a quarter of an inch in the breadth may ftand out from between the boards. Then fix up thefe pieces horizontally againft the wall under your pole, and therewith, as with a beam-compafs, ftrike an arch upon each of them; then file each of them with a fmooth file to the arch ftruck, fo as one may be a convex and the other a concave arch of the fame circle. Thefe braffes are the gages to keep the fpeculum, and the tools on which it is ground, always to the fame fphere: and that they may be, therefore, perfectly true to each other, it is neceffary to grind them with fine emery one againft the other, laying them on a flat table for that purpofe, and fixing one of them to the table. When the gages are perfectly true, let a piece of wood be turned about two-tenths of an inch broader than the intended fpeculum, which it is beft to caft in no cafe lefs than two-tenths of an inch thick; and for fpecula of fix, eight, or ten inches broad, this fhould be at leaft three or four-tenths thick when finifhed. This board being turned, take fome common pewter, and mix with it about one-tenth of regulus of antimony, and with that wooden pattern, caft one of this pewter, which will be confiderably harder than common pewter. Let this pewter pattern be truly turned in a lathe, and examined by means of the gages before-mentioned, as a pattern for cafting the fpecula themfelves; and take care, when it is turned, that it be at leaft one-twentieth of an inch thicker, and about one-tenth of an inch broader than the fpeculum intended to be caft from it. The manner of making the moulds for cafting is now to be explained, and will ferve for a direction as well for cafting this pewter pattern, as afterwards for cafting thereby the fpeculum itfelf. The flafks fhould be of iron, and at leaft two inches wider every way than the fpeculum intended. In each flafk there fhould be the thicknefs at leaft of one inch of fand. The cafting-fand which the common founders ufe will anfwer the purpofe as well as any; and any fand will do which is naturally mixed with a fmall proportion of clay, to make it ftick. The fand fhould be as little wet as may be, and well beaten, but not too hard. The ingates fhould be cut fo as to let the metal flow in, in four or five ftreams, over the whole upper part of the mould; otherwife, whatever pores happen in the metal will not be fo equally difperfed as they fhould be over the whole face of the metal, thefe pores generally falling near the ingate ftreams. Let the flafks dry in the fun for fome hours, or near a very gentle fire, otherwife they will warp, and give the fpeculum, when caft, a wrong figure: for, befides faving the trouble in grinding, it is beft, on many accounts, to have the fpeculum caft of a true figure; and for this reafon it is beft to caft it from a hard pewter pattern, and not from a wooden one, as founders ufually caft.

For the compofition of the metal and manner of cafting it, fee SPECULUM. When the metal is caft, the next bufinefs is to grind and polifh it, for which, fays Mr. Mudge, four tools are all that are neceffary, *viz.* 1. The rough-grinder, for working all the rough face of the metal: this is beft made of lead, ftiffened with about a fifth or fixth part of tin; it fhould be at leaft a third more in diameter than the metal which is to be ground; and for one of any fize, not lefs than an inch thick. It may be cemented on a block of wood, in order to raife it higher from the bench.

This leaden tool being caft, muft be fixed in the lathe, and turned as true as poffible by the gage to the figure of the intended fpeculum, making a hole in the middle, as a lodgment for the emery, of about an inch diameter, for a metal of four inches: when this is done, deep grooves muft be cut acrofs its furface with a graver, in the manner reprefented in *Plate* V. *Optics*, *fig.* 6; thefe grooves will ferve to lodge the emery, and by their means the tool will cut much fafter. Any kind of low handle, fixed on the back of the metal with foft cement, will be fufficient; but it fhould cover two-thirds of its back, to prevent its bending.

2. The next tool is the convex brafs-grinder, on which the metal is to receive its fpherical figure. In order to form this tool, procure a round ftout piece of Hamburgh brafs, at moft a fixth part larger than the metal to be polifhed; and let it be well hammered into a degree of convexity, by the affiftance of the gage, fuitable to the intended fpeculum: then fcrape and clean the concave fide fo thoroughly, that it may be well tinned all over; then caft upon it, after it has been preffed a proper depth into the fand, the former compofition of tin and lead in fuch a quantity, that it may, for a fpeculum of four inches diameter, be at leaft an inch and a half thick, and with a bafe confiderably broader than the top, in order that they may ftand firmly upon the bench in the manner hereafter to be defcribed. This being done, it muft be fixed and turned in the lathe with great care, and of fuch a convexity as exactly to fuit the concave gage. This tool muft have a hole, fomewhat lefs than that in the metal to be worked upon it, in the middle, quite through to the bottom. When it is finifhed off in the lathe, its diameter fhould be one-eighth wider than the metal.

The 3d tool is the bed of hones, the ufe of which is to perfect the fpherical figure, and to give the metal a fine fmooth face. See *Bed of* HONES.

The 4th and laft tool is the bruifer, with which both the brafs-grinder and the hones are to be formed; this tool fhould be made of thick ftout brafs, perfectly found, about a quarter of an inch thick, and hammered as near to the gage as poffible; it fhould be then fcraped, cleaned, and tinned on the convex fide, as the fecond tool was on the concave, and the fame thicknefs of lead and tin caft upon it. This fhould be as broad at bottom as at top; and when it is fixed in the lathe, and turned off concave to the convex gage with accuracy, the diameter ought to be of a middle fize between the hones and the polifher or brafs grinder, which is ufed for this purpofe. Having with the lathe roughly formed the convex brafs grinder, the bed of hones, and the concave bruifer, the convex and concave brafs tools and the metal muft be wrought alternately and reciprocally upon each other with fine emery and water, fo as to keep them to the fame figure as nearly as poffible, in order to which fome wafhed emery muft be procured, by putting it into a bottle,

half filling the bottle with water, and shaking the mixture; so that the coarsest of the emery will subside to the bottom first, and the finest remain at the top: when fresh emery is laid on the tools, it is best done by gently shaking the bottle, and pouring out a small quantity of the turbid mixture. The next operation is to grind the brass convex tool with the bruiser upon it, which is continued for about a quarter of an hour, and then the convex tool is wrought upon the bruiser in the same manner. When these have been wrought on each other, occasionally adding fresh emery, till the vestiges of the turning tool are got out and both brought nearly to a figure, the same form must be given to the metal, by grinding it upon the brass tool with the same kind of emery; taking care, however, by working the two former tools frequently together, to keep all three exactly in the same curve. The best kind of handle for the metal is made of lead, a little more than double its thickness, and somewhat less in diameter, of about three pounds weight, with a hole in the middle, a little larger than that in the metal: the handle should be cemented on with pitch. The upper edge of this weight must be rounded off, that the fingers may not be hurt, and a groove, about the size of the little finger, be turned round just below it, for the more conveniently holding and taking the metal off the tools. When the bruiser, brass tool, and metal, are all brought to the same figure, and have a good surface, the next part of the process is to give a correct spherical figure and a fine face to the metal, upon the hones; these, however, should be covered with water for at least an hour before they are used, otherwise they will be liable to alter their figure; and they must be never suffered to grow dry whilst they are in use, for the same reason.

In order to give a proper figure to the hones, corresponding to that of the brass tool, bruiser, and metal, when they are fixed down to the block, some common flour emery, unwashed, with a good deal of water must be put upon them, and the bruiser being placed upon the hones, and rubbed over them with a few strokes and a light hand, the inequalities of the stone will be soon worn off, the mud that is generated being washed away, every quarter of a minute, with a great deal of water. As soon as the hones have received the general figure of the bruiser, and all the turning strokes are worn out from them, the emery must be carefully washed off, and cleared from the joints with a brush under a stream of water. The bruiser and metal must be likewise cleared in the same manner. The hones being fixed down to the block, the bruiser must be worked upon them with very cautious, regular, short strokes, forward and backward, to the right and left, turning the axis of the bruiser in the hand while you move round the hones, by shifting your position, and walking round the block. The manner of conducting this operation is minutely described by Mr. Mudge. The metal may then be rubbed upon the hones in the same cautious manner, occasionally rubbing the bruiser upon the hones, in order to sharpen them. When in this way the hone pavement has given a fine face and true figure to the metal, you may proceed to try the metal and judge of its figure, by washing the hone-pavement quite clean; then putting the metal upon the centre of it, and giving two or three light strokes round and round only, without carrying the edges of the metal much over the hones; this will take out the order of straight strokes; then having again washed the hones and placed the speculum upon their centre, with gentle pressure, slide it towards you till its edge be brought a little over that of the hones; then carry it quite across the diameter as far as the other side, and having given the metal a light stroke or two in this direction, take it off the tool. The metal being wiped quite dry, place it upon a table at a little distance from a window; stand as near the window, at some distance from the metal, and looking obliquely on its surface, turn it round its axis, and you will see at every half turn the grain given by the last cross strokes flash upon your eye at once over the whole face of the metal. This is a certain proof of a true spherical figure.

The last operation is that of polishing the speculum, and this is the most difficult and essential part of the whole process. Mr Mudge, having made some strictures on the method of Messrs. Hadley and Molyneux, generally followed, describes at large that which he has discovered after a number of trials, both of giving a correct parabolic figure and an exquisite polish at the same time. Availing himself of the manner of polishing with pitch practised by sir Isaac Newton, and mentioned in his Optics, he formed his polisher by coating the brass convex tool equally with pitch, which should be neither very hard and resinous nor too soft, about the thickness of a shilling, and by applying the bruiser to it, gave the pitch upon the polisher a fine surface and the true form of the bruiser. He then divided the leaden weight upon the back of the metal into eight parts, by strokes on the surface of the lead, which are marked with the numbers 1, 2, 3, 4, &c. in order to distinguish and regulate the turns of the metal. He also put half an ounce of putty into an ounce phial, and filled it two-thirds with water; and having shaken the whole, let the putty subside, and stopped the bottle with a cork: the other appendages of his apparatus are a small-sized camel's hair brush in a tea-cup with a little water, a piece of dry clean soap in a galley-pot, and a soft piece of sponge. These, as well as the metal, bruiser, and polisher, should be constantly covered from dust.

The polisher being fixed down, is brushed over with the camel's hair brush, after it has been wetted and rubbed a little over the soap; then the bruiser is worked lightly upon it, till it has acquired a good face and is fit for the metal. Then, having shaken up the putty in the phial, and touched the polisher in five or six places with the cork wetted with that and the water, the bruiser is placed upon the tool, and a few strokes given to it upon the putty, in order to rub down any gritty particles: after which, having removed it, the metal is worked lightly upon the polisher round and round, carrying the edges of the speculum, however, not quite half an inch over the edge of the tool, and now and then with a cross stroke. The putty is repeatedly applied in the same manner, and wrought into the pitch in the course of the operation; and if the bruiser be apt to stick, and does n slide smoothly the pitch, the surface of either tool may be occasionally brushed over with the soap and water. After some continuance of this process, the pitch is well defended by the coating of the putty, and the metal, pressed only by its own weight and that of the handle, and occasionally moistened, moves over it with a more uni- and regular friction. When the polish of the metal nearly reaches the edge, the round strokes must be gradually altered for the short and straight ones. When this has been done for some time, in the manner minutely described by Mr. Mudge, the metal will begin to move stiffly as the friction increases, and the speculum polishes very beautifully and speedily, and the whole surface of the polishing tool will be equally covered over with a fine metallic bronze. As the metal wears much, its surface must be now and then cleaned with a piece of shammy leather, and the polisher likewise with a soft piece of wet sponge. You will now be able to

judge of the perfect spherical figure of the metal and tool, when there is a perfect correspondence between the surfaces, by the fine equable feel there is in working, which is totally free from all jerks and inequalities. Having proceeded thus far, you may put the last finishing to this figure of the metal by bold cross strokes, only three or four in the direction of each of the eight diameters, turning the metal at the same time: this must be done quickly; for, if the tool be suffered to grow quite dry, you will never be able, with all your force, to separate that and the metal, without destroying the polisher by heat. The metal will now have a beautiful polish, and a true spherical figure, but will by no means make a sharp distinct image in the telescope; for the speculum will not be found to make parallel rays converge without great aberration: and, indeed, the deviation will be so great, as to be very sensibly perceived by a great indistinctness in the image.

Supposing then the metal to be now truly spherical, stop the hole in the polisher, by forcing a cork into it underneath, about an inch, so that it do not reach quite to the surface; and having washed off any mud that may be on the surface of the tool with a wet soft piece of sponge, whilst the surface of it is a little moist, place the centre of the metal upon the middle of the polisher; then having, with the wet brush, lodged as much water round the edge of the metal as the projecting edge will hold, fill the whole of the metal and its handle with water, to prevent the evaporation of the moisture, and the consequent adhesion between the speculum and polisher, and let the whole rest in this state for two or three hours: this will produce an intimate contact between the two, and by parting with any degree of warmth they may have acquired by the nearness of the operator, they will become perfectly cold together. By this time you may push out the cork from the polisher to discharge the water, and give the metal the parabolic figure, in the following manner: move the metal gently and slowly at first, a very little round the centre of the polisher, then increasing by degrees the diameter of these strokes, and turning the metal frequently round its axis, give it a larger circular motion, without any pressure, but its own weight: this manner of working may safely be continued about two minutes, moving yourself, as usual, round the block, and carrying the round strokes, in their increased and largest state, not more than will move the edge of the metal half an inch or five eighths over the tool. The speculum must not all this while be taken off from the polisher, and consequently no fresh putty can be added. It will not be safe to continue this motion longer than the time abovementioned; for if the parabolic tendency be carried in the least too far, it will be impossible to recover a true figure of that kind, but by going through the whole process for the spherical one in the manner before described, by the cross-strokes upon the polisher, which takes a great deal of time.

In order to try the true figure of the speculum, place it in the telescope for which it is intended, and use the instrument as a kind of microscope, moving the object to such a distance that the rays may be nearly parallel. At about twenty yards a watch-paper, or some such object, on which there are some very fine hair-strokes of a graver, is fixed up. The lead must be taken off from the speculum, the speculum placed on the cell of the tube, and the instrument directed to the object; make an annular kind of diaphragm with card-paper, so as to cover a circular portion of the middle part of the metal between the hole and the circumference, equal in breadth to about an eighth part of the diameter of the speculum; this paper ring should be fixed in the mouth of the telescope, and remain so during the whole experiment, for the part of the metal covered by it is supposed to be perfect, and therefore unemployed.

There must likewise be two other circular pieces of card-paper cut out, of such sizes, that one may cover the centre of the metal by completely filling the hole in the last described annular piece; and the other, such a round piece as shall exactly fit into the tube, and so broad, as that the inner edge may just touch the outward circumference of the middle annular piece. It would be convenient to have these two last pieces so fixed to an axis, that they may be put in their places or removed from thence so easily as not to displace or shake the instrument. All these pieces therefore together will completely shut up the mouth of the telescope.

Let the round piece which covers the centre of the metal, or that which has no hole in it, be removed; and, by a nice adjustment of the screw, let the image (which is now formed by the centre of the mirror) be made as sharp and distinct as possible. This being done, every thing else remaining at rest, replace the central piece, and remove the outside annular one, by which means the circumference only of the speculum will be exposed, and the image now formed will be from the rays reflected from the outside of the metal. If there be no occasion to move the screw and little metal, and the two images formed by these two portions of the metal be perfectly sharp and equally distinct, the speculum is perfect, and of the true parabolic curve; or at least the errors of the great and little speculum, if there be any, are corrected by each other.

If, on the contrary, under the last circumstances, the image from the outside of the metal should not be distinct, and it should become necessary, in order to make it so, that the little speculum be brought nearer, it is plain that the metal is not yet brought to the parabolic figure; but if, on the other hand, in order to procure distinctness, you be obliged to move the little speculum farther off, then the figure of the great speculum has been carried beyond the parabolic, and hath assumed an hyperbolic form. When the latter is the case, the circular figure of the metal must be recovered (after having fixed on the handle with soft pitch) by bold cross strokes upon the polisher, finishing it again in the manner above described. If the speculum be not yet brought to the parabolic form, it must cautiously have a few more round strokes upon the polisher: indeed a very few of them, in the manner before described, make in effect a greater difference in the speculum than would be at first imagined. If a metal of a true spherical figure were to be tried in the above-mentioned manner in the telescope (which Mr. Mudge has frequently done), the difference of the foci of the two segments of the metal would be so considerable, as to require two or three turns of the screw to adjust them; so very great is the aberration of the spherical figure of the speculum, and so improper to procure that sharpness and precision so necessary to a good reflecting telescope.

Supposing that the two foci of the different parts of the metal perfectly coincide, and that by the union of them, when the apertures are removed, the telescope shews the objects very sharp and distinct, you are not however then to conclude that the instrument is not capable of farther improvement; for you will perceive a sensible difference in the sharpness of the image, under diffrent positions of the great speculum with respect to the little one, by turning round the great metal in its cell, and opposing different parts of it to different parts of the little metal, correcting by this means the error of one by the other. This attempt should be persevered in for some time, turning round the great speculum about one-sixteenth at a time, and carefully observing the most distinct situation each time the eye-piece is screwed on: when, by trying and turning the great metal all round,

the diftinct pofition is difcovered, the upper part of the metal fhould be marked with a black ftroke, in order that it may always be lodged in the cell in the fame pofition. This is the method Mr. Short always ufed; and the caution is of fo much confequence, that he thought it neceffary to mention it very particularly in his printed directions for the ufe of the inftrument.

And farther, Mr. Short frequently corrected the errors of the great by the little metal in another way. If the great fpeculum did not anfwer quite well in the telefcope, he cured that defect, fometimes by trying the effect of feveral metals fucceffively, by this means correcting the errors of one by the other.

The apparatus above-defcribed, for examining the parabolic figure of the fpeculum, is reprefented in *Plate* V. *Optics, fig.* 7: A A is the mouth of the telefcope, or edge of the great tube; B B is a thin piece of wood faftened into and flufh with the end of the tube, to which is permanently fixed the annular piece of pafteboard *c c*, intended to cover and to prevent the action of the correfponding part of the fpeculum. D is another piece of pafteboard, fixed by a pin to the piece of wood B B, on which it turns as on a centre; fo that the great annular opening H H may be fhut up by the ring F F, or the aperture G G by the imperforate piece E, in fuch manner that, in the firft inftance, the reflection may be from the centre, and in the latter, from the circumference of the great fpeculum.

Mr. Mudge has remarked, that the operation of polifhing will not proceed well in the heat of fummer or the cold of winter; and that neither this, nor the other of grinding upon the the hones, will go on fo well, unlefs they be continued uninterruptedly from beginning to end. In the above account it has been fuppofed, that the metal to be wrought was about four inches diameter; if it be either larger or fmaller, the fizes of the hones, bruifer, and polifher, muft be proportionably different.

The procefs for polifhing the little fpeculum of a telefcope muft be conducted in the manner already defcribed, for that of the large one; only obferving, that as the little metal has an uninterrupted face, without a hole, fo there is no occafion for one in the polifher; and likewife that, as the fpherical figure is the only object in this cafe to be attempted, the difficulty of execution is much lefs than in the former. As it is always neceffary to folder to the back of the little fpeculum a piece of brafs, as a fixture for the fcrew to adjuft its axis; Mr. Mudge has communicated a neat and fafe method of doing it, which he received from the late Mr. Jackfon, and which may be very ufeful to the optical or mathematical inftrument-maker upon other occafions. Having cleaned the parts to be foldered very well, cut out a piece of tin-foil the exact fize of them; then dip a feather into a pretty ftrong folution of fal ammoniac in water, and rub it over the furfaces to be foldered; after which place the tin-foil between them as faft as you can (for the air will quickly corrode their furfaces fo as to prevent the folder taking), and give the whole a gradual and fufficient heat to melt the tin. If the joints to be foldered have been made very flat, they will not be thicker than a hair: though the furfaces be ever fo extenfive, the foldering may be conducted in the fame manner, only that care muft be taken, by general preff. , to keep them clofe together. In this manner, for inftance, a filver graduated plate may be foldered on to the brafs limb of a quadrant, fo as not to be difcernible by any thing but the different colour of the metals.

We fhall clofe this article with obferving, that a method of giving the parabolic figure to his great fpeculum was a point of perfection which Gregory and Newton had wifhed for, but defpaired of attaining, and which Hadley does not appear to have attempted either in his Newtonian or Gregorian telefcope. Mr. Short is faid to have poffeffed the fe ret; however, it died with that ingenious artift. The method difcovered by Mr. Mudge, above recited, is, as he has ftrong reafon to believe, the fame with that of Mr Short. See farther on this fubject Smith's Optics, book iii. chap. ii. and Mr. Mudge's excellent paper in the Phil. Tranf. vol. lxvii. part i. art. 16. p. 296—348. See TELESCOPE.

GRINDING is alfo ufed for a coarfer and lefs accurate method of fmoothing or polifhing the furface of a body, particularly glafs for looking-glaffes, &c.

In the new method of working large plates of glafs for looking-glaffes, coach-glaffes, &c. by moulding, and, as it were, cafting them, fomewhat after the manner of metals, defcribed under the article GLASS, the furface being left uneven, it remains to be ground and polifhed. In order to this, the plate of glafs is laid horizontally on a ftone in manner of a table, and to fecure it the better, plaftered down with mortar or ftucco, that the effort of the workman, or of the machine ufed therein, may not fhake or difplace it; to fuftain it, there is a ftrong wooden frame that furrounds it an inch or two higher than the glafs: the bottom or bafe of the grinding engine is another rough glafs about half the dimenfions of the former; on this is a wooden plank, cemented to it; and upon this are proper weights applied, to promote the triture, the plank or table being faftened to a wheel, which gives it motion. This wheel, which is at leaft five or fix inches diameter, is made of a very hard but light wood, and is wrought by two workmen placed againft each other, who pufh and pull it alternately; and fometimes, when the work requires it, they turn it round. By fuch means, a conftant mutual attrition is produced between the two glaffes, which is favoured by water and fands of feveral kinds beftowed between; fand ftill finer and finer being applied, as the grinding is more advanced; at laft emery is ufed. We need not add, that as the upper or incumbent glafs polifhes and grows fmoother, it muft be fhifted from time to time, and others put in its place.

It is to be noted, that only the largeft fize glaffes are thus ground with a mill; for the middling and fmaller forts are wrought by the hand; to which end there are four wooden handles at the four corners of the upper ftone or carriage, for the workmen to take hold of, and give it motion. What remains to the perfection of glafs, comes under the denomination of *polifbing*, which fee.

Gun Flint

Gun *Flint*, in *Technological Mineralogy*. The mode of manufacturing gun-flints, as we have observed in the article Flint, has for a long time been involved in fable and mystery: indeed, even in the Mémoires de l'Académie de France, we are told, "that there is never a deficiency of flints in those countries where they have once been found; that, as soon as a quarry appears exhausted it is shut up; and that when after a certain number of years it is re-opened, the flints are found there under the same circumstances as before." The same erroneous idea is repeated in the French Encyclopédie, and other works; and it was not till lately that we have been made fully acquainted (by Hacquet of Vienna and by Dolomieu) with the simple manner of manufacturing gun-flints in Gallicia and France, where they constitute an important article of commerce. The latter of the above naturalists has given an account of it in the Mém de l'Institut National des Sciences (Classe Mathématique et Physique, t. 3. an. ix.); the former in a monograph on this subject, written in the German language.

In France, the best flints are found in the neighbourhood of St. Aignan, in the department of the Loir-et-Cher, and in that of the Indre, and the departments that occupy the vallies of Seine-et-Marne: they occur as horizontal banks in fletz-limestone, particularly chalk, and also in marle. Among twenty of such beds, or layers, situated one above the other at the distance of about twenty feet, there is generally only one, very seldom two, that furnish good gun-flints: all those of a good quality are coated with a white earthy rind. (See Flint.) On the banks of the Cher, the flints are excavated by means of shafts of forty to fifty feet in depth, from whence levels or horizontal galleries are carried into the only good stratum which is known in that district; but on the banks of the Seine, in the hillocks of Rocheguyon, where the cliffs of chalks present broken precipices, the beds of flint are laid open to view: one of these beds, which contains the good sort, is at about six fathoms distance from the upper surface of the great mass of chalk.

The characters by which the good flints are distinguished from those less fit for being manufactured are the following: Their surface is rather convex, approaching to globular; those that are amorphous, or of a very irregular form, such as knobbed, branched, &c. are generally full of imperfections. Good flint nodules seldom exceed the weight of twenty pounds; nor are those that weigh less than one or even two pounds considered as being of a good quality. Internally they should appear unctuous and rather shining, with a grain too fine to be perceptible to the eye. The colour may vary from honey-yellow to blackish brown; but the tint should be uniform in the same nodule. Their transparency should be sufficient to admit letters to be distinguished through a piece of the stone of a quarter of a line thick, laid close upon the paper. Their fracture should be perfectly smooth and equal throughout, and the fragments slightly conchoidal. The last of these properties is the most essential, since on it depends the facility with which the nodule is divided into gun-flints. All flints that prove deficient in any one of the above characters, either naturally or by a long exposure to the air, are called *intractable*, and rejected by the workmen.

The tools made use of by the *caillouteurs* (a name given to the makers of gun-flints in France) are four in number: 1. A hammer or mace of iron with a square head (*Pl.* II. *Geology*, *fig.* 1.), the weight of which does not exceed two pounds; (but it may be of half that weight only,) with a handle of seven or eight inches long. This tool is not made of steel, for an excess of hardness would render the strokes too hard or dry (as the phrase is), and would shatter the nodules irregularly, instead of breaking them by a clear fracture.

2. A hammer with two points (*fig.* 2.) This is made of good steel, well hardened; its weight does not exceed sixteen ounces; indeed it may weigh ten ounces only. Its handle is seven inches long, passing through it in such a manner that the points of the hammer are nearer the hand of the workman, than the centre of gravity of the mass. The form and size of the hammers of different workmen vary a little; but this disposition of the points is common to them all, and is of consequence to the force and certainty of the blow.

3. The disk-hammer, or roller, a small tool, called in French *roulette*, which represents a solid wheel, or segment of a cylinder, two inches and four lines in diameter (*fig.* 3.): its weight does not exceed twelve ounces. It is made of steel not hardened, and is fixed on a handle six inches in length, which passes through a square hole in the centre.

4. A chissel tapering and bevilled at both extremities (*fig.* 4.), seven or eight inches long, and two inches wide, made of steel not hardened: this is set on a block of wood, which, at the same time, serves as a bench for the workmen.

To these four tools we may add a file, for the purpose of restoring the edge of the chissel from time to time.

After having selected a good mass of flint, the following four operations are performed by the workman.

1. *To break the block*.—The workman, being seated on the ground, places the nodule of flint on his left thigh, and applies slight strokes with the square hammer, to divide it

into ſmaller pieces of about a pound and a half each, with broad ſurfaces, and almoſt even fracture. The ſtrokes ſhould be moderate, leſt the maſs crack and ſplit in the wrong direction.

2. *To cleave or chip the flint.*—The principal operation is to ſplit the flint well, or to chip off ſcales of the length, thickneſs, and ſhape adapted, to be afterwards faſhioned into gun-flints. In this part the greateſt degree of addreſs and certainty of manipulation are required. The fracture of the flint is not confined to any particular direction; it may be chipped in all parts with equal facility.

The workman holds the piece of flint in his left hand, not ſupported, and ſtrikes with the pointed hammer, No. 2, on the edges of the great planes produced by the firſt breaking, by which means the white coating of the flint is removed in the form of ſmall ſcales, and the maſs of the flint itſelf laid bare in the manner repreſented, *fig.* 5; after which he continues to chip off ſimilar ſcaly portions from the pure maſs of the flint. Theſe ſcaly portions are nearly one inch and a half wide, two inches and a half long; and their thickneſs, in the middle, is of about two lines. They are ſlightly convex below, and conſequently leave in the part of the flint from which they were ſeparated a ſpace ſlightly concave, longitudinally bordered by two, rather projecting, ſtraight lines or ridges, *fig.* 6. Theſe ridges, produced by the ſeparation of the firſt ſcales, muſt naturally conſtitute nearly the middle of the ſubſequent pieces; and ſuch ſcales alone as have their ridges thus placed in the middle are fit to be made into gun-flints. In this manner the workman continues to ſplit or chip the maſs of flint in various directions, until the defects uſually found in the interior render it impoſſible to make the fractures required, or until the piece is reduced too much to receive the ſmall blows by which the flint is divided.

3. *To faſhion the gun-flint.*—Five different parts may be diſtinguiſhed in a gun-flint. 1. The ſloping facet, or bevil part, which is impelled againſt the hammer of the lock of the gun: it is called by the French *mèche.* Its width ſhould be from two to three-twelfths of an inch: if it were broader it would be too liable to break; and if more obtuſe, the ſcintillation would be leſs briſk. 2dly. The ſides, or lateral edges, which are always rather irregular. 3dly. The back, or the part oppoſite the tapering edge: this is the thickeſt part of the flint. The French call it *talon.* 4thly. The under ſurface, which is uninterrupted and rather convex. And, 5thly. The upper face, a ſmall ſquare facet between the tapering edge and the back, which receives the upper claw of the cock; it is ſlightly concave. The French term for it is *aſſis.*

In order to faſhion the flint, thoſe ſcales are ſelected that have at leaſt one of the above-mentioned longitudinal ridges: the workman fixes on one of the two tapering borders to form the ſtriking edge; after which, the two ſides of the ſtone that are to form the lateral edges, as well as the part which is to form the back, are ſucceſſively placed on the edge of the chiſſel in ſuch a manner, that the convex ſurface of the flint, which reſts on the fore-finger of his left hand, is turned towards that tool. He then, with the roulette, applies ſome ſlight ſtrokes to the flint juſt oppoſite the edge of the chiſſel underneath; by which means the flint breaks exactly along the edge of the chiſſel.

4. The finiſhing operation is the trimming, or the proceſs of giving the flint a ſmooth and equal edge; this is done by turning the ſtone, and placing the edge of its tapering end on the chiſſel, in which ſituation it is completed by five or ſix ſlight ſtrokes with the roulette. This is termed *roſſiler* by the French workmen.

The whole operation of making a gun-flint is performed in leſs than one minute. A good workman is able to manufacture a thouſand good chips or ſcales a day (if the flint nodules be of a good quality); and in the ſame manner he can faſhion 500 gun-flints in a day; ſo that in the ſpace of three days he is able to cleave and finiſh a thouſand gun-flints without farther aſſiſtance.

This work leaves a great quantity of refuſe, for ſcarcely more than half of the ſcales are good, and nearly half the maſs in the beſt flints is incapable of being chipped out, ſo that it ſeldom happens that the largeſt nodules will furniſh more than fifty gun-flints. Such ſcales as have a cruſt, or are too thick to be made into gun-flints, are uſed for the more common culinary purpoſe of ſtriking a light. Thoſe that are ſold at Paris are brought from the banks of the Seine, and are generally of a brown colour.

The gun-flints are ſorted out according to their perfection, and the uſe to which they are to be applied. They are claſſed into extra and common flints; flints for piſtols, muſkets, and fowling-pieces.

Gunpowder

GUNPOWDER, a composition of nitre, sulphur, and charcoal, mixed together, and usually granulated, which easily takes fire, and, when fired, rarefies, or expands, with great vehemence, by means of its elastic force.

It is to this powder we owe all the action and effect of guns, ordnance, &c. so that the modern military art, fortification, &c. depend almost wholly upon it.

It has been easily discovered, that saltpetre or nitre is not indispensibly necessary in the composition of gunpowder; and that it may be supplied by other substances. New gunpowder was some time ago made in France of double the strength of the old, without any nitre; and Dr. Hutton tried some of it in 1790 at Woolwich, and found that it was about double the strength of the ordinary sort. The substitute for nitre is the like quantity of the marine acid. This, however, is an expensive article; and it is attended with the inconvenience of taking fire and exploding, from a very small degree of heat, and even without the aid of a spark. Some chemists have proposed to substitute for nitre the oxymuriat of pot-ash, and it has been found from experiments, sufficiently decisive, that gunpowder thus made exceeds with respect to energy of explosion the common powder. But oxymuriats act differently from mixtures with nitre; they exert their power suddenly and in a very small space, so as to be very destructive; but in projectile force they are inferior to gunpowder. These have also the dangerous quality of exploding with moderate friction. Some persons, misled by an experiment of Dr. Hales, which shews that burning sulphur does not generate elastic air, but diminishes the quantity of common air, have imagined that sulphur was an unnecessary and even injurious ingredient of gunpowder. But M. Beaumé has found by experiments, that the force of gunpowder was nearly doubled by addition of the sulphur. Sulphur, indeed, is not necessary for the explosion of gunpowder, as the other two ingredients, well mixed, will explode; but it serves to diffuse the fire instantaneously through the whole mass of powder. The advantage, however, of using sulphur seems, from some late experiments in France, applicable for increasing the force of explosion only to small charges; but in quantities of some ounces, the explosive, or at least the projecting, force of powder without sulphur is as considerable as it is with it.

The invention of gunpowder is ascribed, by Polydore Virgil, to a chemist; who accidentally put some of this composition in a mortar, and covered it with a stone, when it happened to take fire, and blew up the stone.

Thevet says, the person here spoken of, was a monk of Fribourg, named Constantine Anelzen; but Belleforet, and other authors, with more probability, suppose him to be Bartholdus Schwartz, or the Black, who discovered it, as some say, about the year 1320; and the first use of it is ascribed to the Venetians in the year 1380, during the war with the Genoese; and it is said to have been first employed in a place anciently called Fossa Clodia, now Chioggia, against Laurence de Medicis; and that all Italy made complaints against it, as a manifest contravention of fair warfare.

But what contradicts this account, and shews gunpowder to be of an older era, is, that Peter Mexia, in his Various Readings, mentions that the Moors, being besieged in 1343 by Alphonsus XI. king of Castile, discharged a sort of iron mortars upon them, which made a noise like thunder; which is seconded by what Don Pedro, bishop of Leon, relates in his chronicle of king Alphonsus, who reduced Toledo, *viz.* that in a sea-combat between the king of Tunis, and the Moorish king of Seville, above four hundred and fifty years ago, those of Tunis had certain iron tubs or barrels, wherewith they threw thunder-bolts of fire.

Du-Cange adds, that there is mention made of gunpowder in the registers of the chambers of accounts in France as early as the year 1338.

Farther, it appears that our Roger Bacon knew of gunpowder near a hundred years before Schwartz was born. That excellent friar tells us, in his treatise "De Secretis Operibus Artis & Naturæ, & de Nullitate Magiæ," cap. 6. which is supposed by some to have been published at Oxford in 1216, and which was undoubtedly written before his Opus Majus, in 1267, "that from salt-petre, and other ingredients, we are able to make a fire that shall burn at what distance we please." Dr. Plott, in his "History of Oxfordshire," p. 236, &c. assures us, that these "other ingredients were explained in a MS. copy of the same

treatise, in the hands of Dr. G. Langbain, seen by Dr. Wallis, to be sulphur and wood coal." The writer of the life of Friar Bacon, in the Biographia Britannica, vol. i. says, that Bacon himself has divulged the secret of this composition in a cypher, by transposing the letters of the two words in chap. xi. of the above cited treatise; where it is thus expressed; "sed tamen salis petræ *lura mope can ubre* (*i. e.* Carbonum pulvere) et sulphuris; et sic facies tonitrum & corruscationem, si scias artificium:" and from hence Bacon's biographer apprehends the words *carbonum pulvere* were transferred to the sixth chapter of Dr. Langbain's MS. In this same chapter Bacon expresly says, that sounds like thunder, and corruscations, may be formed in the air, much more horrible than those that happen naturally. He adds, that there are many ways of doing this, by which a city or an army might be destroyed; and he supposes that, by an artifice of this kind, Gideon defeated the Midianites with only three hundred men. (Judges, chap. vii.) There is also another passage to the same purpose, in the treatise "De Scientia Experimentalia." See Dr. Jebb's edition of the Opus Majus, p. 474.

Mr. Robins apprehends (see the preface to his Tracts), that Bacon describes gunpowder not as a new composition, first proposed by himself, but as the application of an old one to military purposes, and that it was known long before his time. Marcus Græcus, an ancient author, who probably lived about the time of the Arabian physician Mesue, in the beginning of the ninth century, and mentioned by him, in a treatise intitled "Liber Ignium," of which Dr. Mead had a MS. copy, and cited by Dr. Jebb in the preface to Bacon's Opus Majus, describes two kinds of fire-works; one for flying, inclosed in a case or cartouche, made long and slender, and filled with the composition closely rammed, like our modern rocket; and the other thick and short, strongly tied at both ends, and half filled, resembling our cracker; and the composition which he prescribes for both is two pounds of charcoal, one pound of sulphur, and six pounds of salt-petre, well powdered and mixed together in a stone mortar. See CANNON.

Mr. Dutens carries the antiquity of gunpowder much higher; and he refers to the accounts given by Virgil (Æn. lib. vi. ver. 585.), Hyginus (Fabul. 61. and 650.), Eustathius (ad Odyss. λ. 234. p. 1682. l. 1.), Valerius Flaccus (lib. 1. 662.), and others, of Salmoneus' attempt to imitate thunder, presuming from hence that he used a composition of the nature of gunpowder. He adds, that Dion Cassius, in the "Hist. Rom. in Caligul." p. 662, and Johannes Antiochenus, in "Chronica," apud Peiresciana Valesii, Paris, 1604, p. 804, report the same thing of Caligula. The Brachmans did the same, according to Themistius Orat. xxvii. p. 337. and also the Indians, whose practice is recorded by Philostratus, Vita Apol. lib. ii. cap. 33. See likewise lib. iii. cap. 13. Dutens's Inquiry into the Origin of the Discoveries attributed to the Moderns, p. 262, &c. Eng. ed. 1769.

See the preface to the Code of Gentoo Laws, 1776, where it is asserted, that gunpowder was known to the inhabitants of Hindoostan far beyond all periods of investigation.

GUNPOWDER, *Preparation of.* There are divers compositions of gunpowder, with respect to the proportions of the three ingredients, to be met with in pyrotechnical treatises; but the process of making it up is much the same in all.

For some time after the invention of artillery, gunpowder was of a much weaker composition than that now used by us, or that described by Marcus Græcus; which was chiefly owing to the weakness of their first pieces. See GUN and CANNON.

Of 23 different compositions, used at different times, and mentioned by Tartaglia in his Quef. and Inv. lib. iii. quef. 5. the first, which was the most ancient, contained equal parts of nitre, sulphur, and charcoal. When guns of modern structure were introduced, gunpowder of the same composition with the present came also into use. The cannon powder, in the time of Tartaglia, was made of four parts of salt-petre, one of sulphur, and one of charcoal; and the musket powder of 48 parts of salt-petre, seven parts of sulphur, and eight parts of charcoal; or of 18 parts of salt-petre, two parts of sulphur, and three parts of charcoal. The cannon powder was in meal, and the musket powder grained; and it is certain that the invention of graining powder, which is a very considerable advantage, is a modern improvement. (See the preface to Robins's Math. Tracts, p. 32, &c.) The modern composition of it is six parts of nitre to one of each of the other two ingredients: though Mr. Napier says (Trans. of the Irish Acad. vol. ii.) that he finds the strength commonly to be the greatest with the following proportions, *viz.* 3lb. of nitre, about 9 oz. of charcoal, and about 5 oz. of sulphur: the proportion of ingredients in the powder of different nations and different manufactories has been very various. With us the government powder is the same for cannon and for small arms: the difference consisting only in the size of the grains: but in France there have been commonly enumerated three kinds of powder, *viz.* cannon-powder, musket-powder, and pistol-powdes; of each of these again there are two sorts, a stronger and a weaker; all which differences arise only from the various proportions.

The proportions are thus: in the stronger cannon-powder, to every 100 pounds of salt-petre, 25 pounds of sulphur are generally allowed, with the same quantity of charcoal; and in the weaker cannon-powder, to every 100 pounds of salt-petre, 20 pounds of sulphur, and 24 pounds of charcoal. As for the stronger musket-powder, 100 pounds of salt-petre require 18 pounds of sulphur, and 20 of charcoal; and in the weaker, the proportional quantities are 100 pounds of salt-petre, 15 of sulphur, and 18 of charcoal. In the stronger pistol-powder, 100 pounds of salt-petre require 12 of sulphur, and 15 of charcoal; whereas the weaker has to 100 pounds of salt-petre only 10 of sulphur, but 18 of charcoal.

Other authors prescribe different proportions: Semienowitz, for mortars, directs 100 pounds of salt-petre, 25 of sulphur, and as much of charcoal; for great guns 100 pounds of salt-petre, 15 of sulphur, and 18 of charcoal; for muskets and pistols, 100 pounds of saltpetre, eight of sulphur, and ten of charcoal. Macquer, the author of the "Dictionary of Chemistry," recommends 75 parts of purified nitre, 15½ parts of charcoal, and 9½ parts of sulphur.

Miethius extols the proportion of one pound of salt-petre to three ounces of charcoal; or two, or two and a quarter, of sulphur: than which, he affirms, no gunpowder can possibly be stronger. He adds, that the usual practice of making the gunpowder weaker for mortars than guns, as in the example above, is without any foundation, and renders the expence needlesly much greater: for whereas to load a large mortar 24 pounds of common is required, and consequently to load it ten times, 240 pounds; he shews by calculation, that the same effect would be had by 180 pounds of the strong powder.

Mr. Napier has analysed the Chinese powder, and found the proportions of its ingredients to be nearly 100 of nitre, 18 of charcoal, and 11 of sulphur. It was large-grained,

not very ſtrong, but hard, well coloured, and in good preſervation. The French made many trials in 1756 at the royal manufactory of Eſſone, near Paris, for determining the beſt proportions of the component ingredients of powder. Of powder made with nitre and charcoal alone, 16 of nitre and four of charcoal yielded the ſtrongeſt, and gave a power of 9 in the eprouvette. With all theſe ingredients, 16 of nitre, four of charcoal, and one of ſulphur, raiſed the eprouvette to 15, and both a leſs and a greater quantity of ſulphur produced a ſmaller effect. Then diminiſhing the charcoal, a powder of 16 of nitre, three of charcoal, and one of ſulphur, gave a power of 17 in the eprouvette, which was the higheſt produced by any mixture. This laſt was alſo tried in the mortar eprouvette againſt the common proof powder, and was found to maintain a ſmall ſuperiority. The powder made without ſulphur in the proportions above intimated was alſo tried in the mortar eprouvette, and with the following ſingular reſult: when the charge was only two ounces, it projected a 60lb. copper ball 213 feet, and the ſtrongeſt powder with ſulphur projected it 249 feet; but in a charge of three ounces the former projected the ball 475 feet, and the latter only 472 feet: and on the other hand the great inferiority of force in the ſmaller eprouvette of the powder without ſulphur has been juſt noticed." Aikin's Dict.

When the ſeveral ingredients of gunpowder are properly prepared, mixed, and grained, in the manner already recited, if the leaſt ſpark be ſtruck thereon from a ſteel and flint, the whole will be immediately inflamed, and burſt out with extreme violence.

The effect is not hard to account for: the charcoal part of the grain whereon the ſpark falls, catching fire like tinder, the ſulphur and nitre are readily melted, and the former alſo breaks into flame; and at the ſame time the contiguous grains undergo the ſame fate. Now it is known, that ſaltpetre, when ignited, rarefies to a prodigious degree.

Sir Iſaac Newton reaſons thus on the point: the charcoal and ſulphur in gunpowder eaſily take fire, and kindle the nitre; and the ſpirit of the nitre, being thereby rarefied into vapour, ruſhes out with an exploſion much after the manner that the vapour of water ruſhes out of an æolipile; the ſulphur alſo, being volatile, is converted into vapour, and augments the exploſion: add, that the acid vapour of the ſulphur, namely, that which diſtils under a bell into oil of ſulphur, entering violently into the fixed body of the nitre, lets looſe the ſpirit of the nitre, and excites a greater fermentation, whereby the heat is farther augmented, and the fixed body of the nitre is alſo rarefied into fume; and the exploſion is thereby made more vehement and quick.

For if ſalt of tartar be mixed with gunpowder, and that mixture be warmed till it takes fire, the exploſion will be greatly more violent and quick than that of gunpowder alone, which cannot proceed from any other cauſe than the action of the vapour of gunpowder upon the ſalt of tartar, whereby that ſalt is rarefied. See *Pulvis* FULMINANS.

The exploſion of gunpowder ariſes, therefore, from the violent action whereby all the mixture being quickly and vehemently heated, is rarefied and converted into fume and vapour; which vapour, by the violence of that action, becomes ſo hot as to ſhine, and appear in the form of a flame.

Dr. Ingenhouſz accounts for the effect of gunpowder, by obſerving that nitre yields by heat a ſurpriſing quantity of pure dephlogiſticated air, and charcoal a conſiderable quantity of inflammable air; the fire employed to inflame the powder extricates theſe two airs, and ſets fire to them at the inſtant of their extrication. See this theory largely explained in Phil. Tranſ. vol. lxix. part ii. art. 26.

Count Rumford (ſee Phil. Tranſ. for 1797.) is of opinion that the force of the elaſtic fluid, generated in the combuſtion of gunpowder, may be ſatisfactorily accounted for upon the ſuppoſition that its force depends ſolely on the elaſticity of watery vapour or ſteam. For this purpoſe he recurs to the experiments of M. Betancour, publiſhed at Paris, under the auſpices of the Royal Academy of Sciences, in the year 1790, which ſhew that the elaſticity of ſteam is doubled by every addition of temperature equal to 30° of Fahrenheit. From the count's reference it appears that the experiments were carried as far as 280° of that ſcale, in which caſe the preſſure was found to be equal to about four atmoſpheres. He affirms, that there ſeems to be no reaſon why the ſame law ſhould not hold in higher temperatures, and he has therefore extended his computations through 13 more terms of the geometrical ſeries, the laſt of which affords an elaſtic force equal to more than 65,000 atmoſpheres. If, indeed, the deductions from M. Betancour's experiments be admitted, the water of cryſtallization in the nitre, and the moiſture, which the charcoal may be conceived to retain, appear to be fully ſufficient to account for the exploſive force by means of ſteam only. The gaſſes produced by the exploſion of gunpowder have not been analyſed with accuracy ſince the diſcovery of all the variety of gaſſes with the baſis of carbon: but they are certainly carbonic acid, ſulphureous acid gas, and carburetted hydrogen. The reſidue is chiefly a ſulphuret of potaſh formed by a part of the ſulphur uniting with ſome of the alkali of the nitre, and hence proceeds the hepatic ſmell of a foul and damp gunbarrel. Aikin's Dict.

M. de la Hire, in the Hiſtory of the French Academy for 1702, aſcribes all the force and effect of gunpowder to the ſpring or elaſticity of the air incloſed in the ſeveral grains thereof, and in the intervals or ſpaces between the grains; the powder being kindled, ſets the ſprings of ſo many little parcels of air a playing, and dilates them all at once, whence the effect; the powder itſelf only ſerving to light a fire which may put the air in action; after which the whole is done by the air alone.

But it will appear from the experiments and obſervations of Mr. Robins, recited in the ſequel of this article, that if this air be in its natural ſtate at the time when the powder is fired, the greateſt addition its elaſticity could acquire from the flame of the exploſion would not amount to five times its uſual quantity, and, therefore, could not ſuffice for the two hundredth part of the effort, which is exerted by fired powder.

In order to underſtand the force of gunpowder, it muſt be conſidered, that whether it be fired in a vacuum or in air, it produces by its exploſion a permanent elaſtic fluid. For if a red-hot iron be included in a receiver, and the receiver be exhauſted, and the gunpowder be then let fall on the iron, the powder will take fire, and the mercurial gage will ſuddenly deſcend upon the exploſion; and though it immediately aſcends again, yet it will never riſe to the height it firſt ſtood at, but will continue depreſſed by a ſpace proportioned to the quantity of gunpowder which was let fall on the iron. By this means (firing ſmall quantities at a time) the mercurial gage may be reduced from $29\frac{1}{2}$ inches to $12\frac{1}{4}$. Now this experiment, which has been often repeated, proves the propoſition with reſpect to the production of a permanent elaſtic fluid in a vacuum; for the deſcent of the gage could only be effected by the preſſure of ſome new-generated fluid in the receiver, balancing in part the preſſure of the external air. That this fluid, or

ſome part of it at leaſt was permanent, appears from hence, that though in theſe experiments the quickſilver aſcended after the operation, yet, next day it had aſcended no higher than $22\frac{1}{2}$, at which place it ſeemed to continue fixed. And that this fluid is elaſtic, is proved from the deſcent of the mercurial gage; ſince the quantity of matter contained in this fluid could not by its gravity alone have ſunk the quickſilver by the leaſt ſenſible quantity; alſo from its extending itſelf through any ſpace, however great, the experiment ſucceeding in either a large or ſmall receiver, only the larger the receiver the leſs will be the deſcent of the mercurial gage to the ſame quantity of powder; the preſſure of the generated fluid diminiſhing as its denſity diminiſhes. See Phil. Tranſ. No. 295.

The ſame production likewiſe takes place, when gunpowder is fired in the air; for if a ſmall quantity of powder be placed in the upper part of a glaſs tube, and the lower part of the tube be immerged in water, and the water be made to riſe ſo near the top, that only a ſmall portion of air is left in that part where the gunpowder is placed; if in this ſituation the communication of the upper part of the tube with the external air be cloſed, and the gunpowder be fired (which may eaſily be done by a burning-glaſs) the water will, in this experiment, deſcend on the exploſion, as the quickſilver did in the laſt, and will always continue depreſſed below the place at which it ſtood before the exploſion; and the quantity of this depreſſion will be greater, if the quantity of powder be increaſed, or the diameter of the tube be diminiſhed. From whence it is proved, that as well in air as in vacuum, the exploſion of fired powder produces a permanent elaſtic fluid. (Haukſbee, Phyſ. Mechan. Exp. p. 11.) This releaſe of real and elaſtic air from various ſubſtances, in certain circumſtances, is now a well known and inconteſtible fact. See Air.

It alſo appears from experiment, that the elaſticity or preſſure of the fluid produced by the firing of gunpowder, is, *cæteris paribus*, directly as its denſity. This follows from hence, that if in the ſame receiver a double quantity of powder be let fall, the mercury will ſubſide twice as much as in the firing of a ſingle quantity. For the vapour produced from the double quantity, being contained in the ſame receiver, will be of double the denſity of that produced from the ſingle quantity; whence the elaſticity or preſſure, eſtimated by the deſcent of the mercury, being likewiſe double, the preſſure is directly as its denſity. Alſo the deſcents of the mercury, when equal quantities of powder are fired in different receivers, are reciprocally as the capacities of thoſe receivers; and, conſequently, as the denſity of the produced fluid in each.

To determine the elaſticity and quantity of this elaſtic fluid, produced from the exploſion of a given quantity of gunpowder, Mr. Robins premiſes, that the elaſticity of this fluid increaſes by heat, and diminiſhes by cold, in the ſame manner as that of the air (a fact confirmed by ſome later experiments of Mr. Dalton); and that the denſity of this fluid, and conſequently its weight, is the ſame with the weight of an equal bulk of air, having the ſame elaſticity and the ſame temperature. From theſe principles, and from the experiments by which they are eſtabliſhed, for a detail of which we muſt refer to the book itſelf, ſo often cited in theſe articles, he concludes that the fluid produced by the firing of gunpowder will be nearly $\frac{3}{10}$ of the weight of the generating gunpowder; and the ratio of the reſpective bulks of the powder, and the fluid produced from it, will be in round numbers, 1 to 244.

Count Saluce, in his Miſcell. Phil. Mathem. Soc. priv. Taurin. p. 125, makes the proportion as 1 to 222, which, he ſays, agrees with the computation of Meſſrs. Haukſbee, Amontons, and Belidor.

Hence we are certain, that any quantity of powder fired in any confined ſpace, which it adequately fills, exerts at the inſtant of its exploſion againſt the ſides of the veſſel containing it, and the bodies it impels before it, a force at leaſt 244 times greater than the elaſticity of common air, or, which is the ſame thing, than the preſſure of the atmoſphere; and this without conſidering the great addition which this force will receive from the violent degree of heat with which it is endued at that time; the quantity of which augmentation is the next head of Mr. Robins's enquiry. He determines that the elaſticity of the air is augmented, when heated to the extremeſt heat of red-hot iron, in the proportion of 796 to $194\frac{1}{3}$ nearly; and ſuppoſing that the flame of fired gunpowder is not leſs hot than red-hot iron, and the elaſticity of the air, and conſequently of the fluid generated by the exploſion, being augmented by the extremity of this heat in the ratio of $194\frac{1}{3}$ to 796, it follows, that if 244 be augmented in this ratio, the reſulting number, which is $999\frac{1}{3}$, will determine how many times the elaſticity of the flame of fired powder exceeds the elaſticity of common air, ſuppoſing it to be confined in the ſame ſpace which the powder filled before it was fired.

Hence then the abſolute quantity of the preſſure exerted by gunpowder at the moment of its exploſion, may be aſſigned; for ſince the fluid then generated has an elaſticity $999\frac{1}{3}$, or, in round numbers, 1000 times greater than common air; and ſince common air, by its elaſticity, exerts a preſſure on any given ſurface equal to the weight of the incumbent atmoſphere, with which it is in equilibrio; the preſſure exerted by fired powder, before it has dilated itſelf, is 1000 times greater than the preſſure of the atmoſphere, and, conſequently, the quantity of this force on a ſurface of an inch ſquare, amounts to above ſix tun weight; which force, however, diminiſhes, as the fluid dilates itſelf.

Though it has here been ſuppoſed, that the heat of gunpowder, when fired in any conſiderable quantity, is the ſame with iron heated to the extremity of a red heat, or to the beginning of a white heat, yet it cannot be doubted but that the fire produced in the exploſion is ſomewhat varied (like all other fires) by a greater or leſs quantity of fuel; and it may be preſumed, that according to the quantity of powder fired together, the flame may have all the different degrees from that of a languid red heat to the heat ſufficient for the vitrification of metals; but as the quantity of powder requiſite for the production of this laſt mentioned heat is certainly greater than what is ever fired together for any military purpoſe, we ſhall not be far from our ſcope, if we ſuppoſe the heat of ſuch quantities as come more frequently in uſe to be, when fired, nearly the ſame with the ſtrongeſt heat of red-hot iron; allowing a gradual augmentation to this heat in larger quantities, and diminiſhing it when the quantities are very ſmall. Prin. of Gunnery, in Robins's Math. Tracts, vol. i. p. 59, &c.

Gunpowder is ſuppoſed to explode at about 600° Fahr. but if heated to a degree juſt below that of faint redneſs, the ſulphur will moſtly burn off, leaving the nitre and charcoal unaltered.

We may obſerve, that the variations of the denſity of the atmoſphere do not any way alter the action of powder. By comparing ſeveral trials made at noon in the hotteſt ſummer ſun, with thoſe made in the freſhneſs of the morning and the evening, no certain difference could be per-

ceived; and it was the same with those made in the night and in winter. Indeed, considering that the same quantity of that elastic fluid in which the force of powder consists, is generated in a vacuum and in common air, it is difficult to conceive how this force can be affected by the greater or less density of the atmosphere.

But the moisture of the air has a very great influence on the force of powder; for that quantity which in a dry season would communicate to a bullet the velocity of 1700 feet in one second, will not in damp weather communicate a velocity of more than 12 or 1300 feet in a second, or even less, if the powder be bad and negligently kept. Robins's Math. Tracts, vol. i. p. 101, &c.

This agrees with an experiment made before a committee of the Royal Society, where powder having been dried by being put into a phial placed in boiling water, threw a ball out of a mortar twice as far as the same quantity of powder taken out of the same barrel before it was dried.

Now the ranges under the same circumstances of charge, elevation, &c. being as the squares of the velocities of the ball, these velocities, in this experiment, will be to each other nearly as 17 to 12, which give ranges as 289 to 144. Phil. Transf. N° 465. p. 182, 183.

If powder be damp, shot made with equal quantities of it out of the same parcel, will differ considerably from each other, perhaps ten times more than if the powder was in good order. A small charge seems to lose a greater part of its force than a larger, each being equally damp. Another circumstance attending damp powder is, a remarkable foulness in the piece, after firing, much beyond what arises from an equal quantity of dry powder.

That powder will imbibe moisture from the air, and thereby increase in weight, is certain. A parcel of very good powder being placed on a white paper, pierced with a great number of fine holes, and held over the steam of hot water, the powder in half a minute was increased about $\frac{1}{70}$ in weight. Another parcel, continuing longer in the steam, was increased by $\frac{1}{4}$ part. That the moisture of the atmosphere has a like effect, appears from this, that an ounce of powder kept for some time in a room having a fire in it every day, being dried before the fire, lost above $\frac{1}{100}$ part of its weight; one third of which it regained in less than two hours by being removed to a part of the room distant from the fire. And as the air is often much moister than when this experiment was tried, and the open air is more moist than a room with a fire, it cannot be doubted but that the twentieth or thirtieth part of the substance of the best powder is water. Now as a certain quantity of water mixed with powder will prevent its firing at all, it cannot be doubted but every degree of moisture must abate the violence of the explosion; and hence the effects of damp powder are not hard to account for.

It is to be observed, that the moisture imbibed by powder does not render it less active when dried again. Indeed, if powder be exposed to the greatest damps, without any caution, or if common salts abound in it, as often happens through negligence in refining the nitre, the moisture it imbibes may, in such cases, be perhaps sufficient to dissolve some part of the nitre, which is a lasting damage that no drying can retrieve. But when tolerable care is taken in preserving powder, and the nitre it is composed of has been well purged from common salt, it will retain its force much longer than is usually supposed; and it is said that powder has been known to have been preserved for fifty years, without any apparent damage from its age.

Some care is necessary in the drying of damp gunpowder; for there is a degree of heat, which, though not sufficient to fire the powder, will yet melt the brimstone, and destroy the texture of the grains. Nay, more, there is a heat with which the brimstone will flame and burn away gradually, and yet the powder will not explode; of this any one may satisfy himself by heating a piece of iron red-hot, and then throwing a few grains of powder on it at different intervals, during the time of its cooling; for by this means he will find, that at a certain time the separate grains that fall on the iron will not explode, but will burn with a small blue flame for some space of time, the grain still remaining unconsumed. Indeed, when it has begun to burn in this manner, it sometimes ends with exploding; but this more commonly happens when a number of grains lie near together; for then, though each separate flame is not sufficient to explode its respective grain, yet the whole fire made by them altogether grows strong enough at last to end in a general explosion; however, by attending to the proper temperature of the iron, and spreading the grain, two or three inches square may be covered with a blue lambent flame, which will last a considerable time without any explosion, and the grains afterwards will not apparently have lost either their colour or their shape. Now since these grains, when the brimstone is thus burnt or even melted out of them, will no longer act as powder; it is evident that powder may be spoiled by being dried with too violent a heat. Robins, ubi supra, p. 104, &c.

The velocity of expansion of the flame of gunpowder, when fired in a piece of artillery, without either bullet or other body before it, is prodigious. By the experiments of the author so often quoted, it seems this velocity cannot be much less than 7000 feet in a second. But M. Bernouilli and M. Euler suspect that it is much greater; and Dr. Hutton imagines that it cannot be less at the moment of explosion than four times as much. This, however, must be understood of the most active part of the flame. For, as was observed before, the elastic fluid, in which the activity of gunpowder consists, is only $\frac{3}{10}$ of the substance of the powder, the remaining $\frac{7}{10}$ will, in the explosion, be mixed with the elastic part, and will by its weight retard the activity of the explosion; and yet they will be so completely united, as to move with one common motion; but the unelastic part will be less accelerated than the rest, and some of it will not be carried out of the barrel, as appears by the considerable quantity of unctuous matter, which adheres to the inside of all fire arms after they have been used. These inequalities in the expansive motion of the flame, render it impracticable to determine its velocity otherwise than from experiments The foundation of which determination is, that a barrel being fixed in a proper situation on a pendulum, such as is described under the head Gunnery, and being charged with twelve penny-weight of powder, without either ball or wad, the powder being only put together by the rammer; on the discharge the pendulum ascended through an arch whose chord was 10 or $10\frac{1}{4}$ inches.

Now if the piece be again loaded with the same quantity of powder rammed down by a wad of tow, weighing one penny-weight, it may be supposed that this wad, being very light, will presently acquire that velocity, with which the elastic part of the fluid will expand itself when uncompressed; and it was accordingly found, that the chord of the ascending arch was by this means augmented to twelve inches; so that by the additional weight of one penny-weight of matter moving with the velocity, of the swiftest part of the vapour, the pendulum ascended through an arch whose chord was two inches longer than before. And by calculating upon these facts, and the principles laid down in his book, Mr. Robins determines that the velocity with which this one penny-weight of matter moved, must be about

7000 feet in one second. It is this prodigious celerity of expansion of the flame of fired gunpowder, which is its peculiar excellence, and the circumstance in which it so eminently surpasses all other inventions, either ancient or modern, for the purpose of military projections: for as to the quantity of motion of these projectiles only, many of the warlike machines of the ancients produced this in a degree far surpassing that of our heaviest cannon-shot or shells; but the great celerity given to these bodies cannot be in the least approached by any other means than by the flame of powder. The reason of this difference is, that the ancients could by weights, or the elasticity of springs and stretched chords, augment their powers to any degree desired; but then each addition of power brought with it a proportional addition of matter to be moved; so that as the power increased, those parts of the machine which were to communicate motion to the projectile, and were consequently to move with it, were likewise increased; and thence it necessarily happened, that the action of the power was not solely employed in giving motion to the impelled body, but much the greatest part of it was spent in accelerating those parts of the machine in which the power resided, to enable them to pursue the body to be projected with perpetual impulse, during its whole passage through the extent of their activity. Hence then it came to pass, that, though these ancient machines could throw enormous weights, they could project them but with small degrees of celerity, compared with what we can communicate to our cannon and musket-shot; whence in all operations, where these great velocities are useful, our machines are infinitely superior to those of antiquity; although, in more confined and shorter projections, these last have some advantage, which may yet render them worthy of the attention of those military geniuses, who have capacity enough to consider each part of the profession according to its true and genuine value, independent of the partial estimation of the times they live in. Ibid. p. 112.

There are several ways of proving the goodness of gunpowder. 1. By sight; for if it be too black, it is too moist, or has too much charcoal in it; so also if rubbed upon white paper, it blackens it more than good powder does: but if it be of a kind of azure colour, somewhat inclining to red, it is a sign of good powder. 2. By touching; for if in crushing it with your fingers' ends, the grains break easily, and turn into dust, without feeling hard, it has too much charcoal in it; or if in pressing under your fingers upon a smooth hard board, some grains feel harder than the rest, or, as it were, dent your fingers' ends, the sulphur is not well mixed with the nitre, and the powder is bad. And also by thrusting the hand into a parcel of powder, and grasping it, as if you were about to take a handful of it, you may feel if it be dry and equally grained, by its evading the grasp, and running mostly out of the hand. 3. By burning, in which method little heaps of powder are laid on white paper three inches or more asunder, and one of them fired; which, if it only fires all away, and that suddenly, and almost imperceptibly, without firing the rest, and makes a small thundering noise, and a white smoke arises in the air almost like a circle, the powder is good; if it leaves black marks, it has too much charcoal, or is not well burnt: if it leaves a greasiness, the sulphur or nitre are not well cleansed or ordered. Again, if two or three corns be laid on paper an inch distant, and fire be put to one of them, and they all fire at once, leaving no sign behind, but a white smoky colour in the place, and the paper not touched, the powder is good. So also if fired in a man's hand, and it burns not; but if black knots appear, which burn downwards in the place where proof was made, after firing, it is not strong enough, but wants nitre. The method most commonly followed for this purpose with us, says Mr. Robins, is to fire a small heap of it on a clean board, and to attend nicely to the flame and smoke it produces, as likewise to the marks it leaves behind on the table; from all which instructive particulars the merit of the powder is ascertained with great accuracy, as is pretended: but besides this uncertain method, which how much soever it may be practised, none will undertake seriously to defend, there are, on particular occasions, other contrivances made use of, all which bear some analogy to the common powder-triers, sold at the shops: only they are more artfully fabricated, and instead of a spring they move a weight, which is a more certain and equal power.

Another method of proving gunpowder, is to take out of several barrels a measure, of about the size of a thimble, which is spread upon a sheet of fine writing paper, and then fired; if the inflammation is very rapid, the smoke rises perpendicularly, and the paper is neither burnt nor spotted, the powder is judged to be good: then two drams of the same powder, being exactly weighed, are put into a machine, called *eprouvette* or gunpowder prover, which, if it raises a weight of 24lb. to the height of $3\frac{1}{2}$ inches, it is allowed to be good.

But these machines, says Mr. Robins, though more perfect than the common powder-triers, are yet liable to great irregularities; for as they are all moved by the instantaneous stroke of the flame, and not by its continued pressure, they do not determine the force of the fired powder with that certainty and uniformity which were to be desired in these kinds of trials: and therefore, the method followed by the French, in the receiving of powders from the makers, seems to be much better. Their practice is thus:

They have, in each magazine, a small mortar cast with its bed, according to a determined pattern, which is the same throughout the kingdom: this mortar is always pointed at 45°, and it contains just three ounces of powder; and it is a standing maxim, that no powder can be received into their stores, unless three ounces of it, placed in the chamber of this mortar, throw a solid ball of $7\frac{1}{2}$ inches diameter to the distance of at least 55 French fathom. But if each barrel of powder was to be proved in this manner, the trouble of changing the mortar, &c. would be intolerable, and the delay so great, that no business of this kind could ever be finished. The method by firing against a pendulum, in the manner mentioned under the head GUNNERY, seems a readier way; but still it requires some nicety and time, which it were to be wished could be obviated. (Robins's Mathemat. Tracts, vol. i. p. 121.) Dr. Hutton has contrived a machine for this purpose, which has several advantages peculiar to itself. It is a small cannon, the bore of which is about one inch in diameter, and it is usually charged with two ounces of powder, and with powder only, as a ball is not necessary, and the strength of the powder is accurately shewn by the arc of the gun's recoil. The whole machine is so simple, easy, and expeditious in its use, that the weighing of the powder is the chief part of the trouble; and it is also so accurate and uniform, that the successive repetitions or firings with the same quantity of the same sort of powder, hardly ever yield a difference in the recoil of the 100dth part of itself.

Count Rumford (see Phil. Trans. vol. lxxi.), having pointed out the insufficiency and the defects of the eprouvettes, or powder triers, in common use, recommends for proving the goodness and strength of powder, the following method: A quantity of powder being provided, which, from any previous examination or trial, is known to be of a proper

degree of ſtrength to ſerve as a ſtandard for the proof of other powder, a given charge of it is to be fired, with a fit bullet, in a barrel ſuſpended by two pendulous rods, (according to the method which the author had previouſly deſcribed in the ſame paper,) and the recoil is to be carefully meaſured upon the ribbon. When this experiment has been ſufficiently repeated, the mean and the extremes of the chords may be marked upon the ribbon by black lines drawn acroſs it, and the word *proof* may be written upon the middle line; or if the recoil is uniform, then the *proof mark* is to be made in that part of the ribbon to which it was conſtantly drawn out by the recoil in the different trials. The recoil, with a known charge of ſtandard powder, being thus aſcertained, and marked upon the ribbon, let an equal quantity of any other powder, (that is to be proved,) be fired in the ſame barrel, with a bullet of the ſame weight; every other circumſtance being alike; and if the ribbon is drawn out as far, or farther than the proof-mark, the powder is as good, or better than the ſtandard; but if it falls ſhort of that diſtance, it is worſe than the ſtandard, and to be rejected. For the greater the velocity is with which the bullet is impelled, the greater will be the recoil; and when the recoil is the ſame, the velocities of the bullets are equal, and the powder is of the ſame degree of ſtrength, if the quantity of the charge is the ſame. And if care is taken in proportioning the charge to the weight of the bullet, to come as near as poſſible to the medium proportion that obtains in practice, the determination of the goodneſs of gun-powder from the reſult of this experiment cannot fail to hold good in actual ſervice. The author has deſcribed his apparatus, and illuſtrated the conſtruction and uſe of it by appropriate figures. Since the charges with the ſame kind of powder are as the ſquares of the velocities of diſcharged bullets, the charge of the weaker powder muſt be to that of the ſtronger, when the velocities are equal, as V V to *v v*; V denoting the velocity of the bullet with the ſtronger powder, and *v* the velocity with the weaker, when the charges are equal, and the weight and dimenſions of the bullet are the ſame, and when they are diſcharged from the ſame piece. The weaker powder therefore is as much worſe than the ſtronger as V V is greater than *v v*; or the comparative goodneſs of powder, of different degrees of ſtrength, is as the ſquares of the velocities of the bullets when the charges are equal. The author, eſtimating the comparative goodneſs of government powder with that of double proof battle powder (ſee Battle), found, by the medium of ſeveral trials, that double proof battle powder is better than government powder in the proportion of 1.2036 to 1, or nearly of 6 to 5. But if inſtead of weighing the powder, we eſtimate the quantity of the charge by meaſurement, or the ſpace it occupies in the bore of the piece, the comparative ſtrength of battle powder will appear to be conſiderably greater, or its ſtrength will be to that of government powder nearly as 4 is to 3; for the grains of this better kind of powder being more compact and nearly of a ſpherical form, a greater weight of it will lie in any given ſpace than of government powder, which is formed more looſely, and of various and very irregular figures. Now the common price of double proof battle powder, as it is ſold by the wholeſale dealers in that commodity, is at the rate of 10*l*. *per cwt*. net, which is juſt two ſhillings *per* pound; while government powder is ſold at 5*l* 5*s* *per cwt*., or 1*s*. and $\frac{9}{10}$ of a penny *per* pound; but battle powder is better than government powder nearly in the proportion of 1.2036 to 1, or of 1*s*. 2*d*. to 1*s*. $\frac{6}{10}$*d*.; battle powder is therefore ſold at the rate of 10*d*. per lb., or 41 *per cent*. dearer than it ought to be; or thoſe who make uſe of it in preference to government powder, do it at a certain loſs of 41⅔ *per cent*. of the money that the powder coſts them.

Gunpowder is a commodity of ſuch conſequence, both in reſpect of ſpeculation, of war, and of commerce (the conſumption thereof being incredible), that it will deſerve a more particular detail. To make gunpowder duly then, regard is to be had, that the ſalt-petre be pure, and in fine large cryſtals or ſhootings; otherwiſe, it is to be purified, by taking away its fixed or common ſalt, and earthy part, thus: diſſolve ten pounds of nitre in a ſufficient quantity of fair water; ſettle, filtrate, and evaporate it in a glazed veſſel, to the diminution of half, or till a pellicle appear on it; the veſſel may then be taken off from the fire, and ſet in a cellar: in twenty-four hours the cryſtals will ſhoot, which ſeparate from the liquor; and after the like manner may the liquor be cryſtallized ſeveral times, till all the ſalt be drawn forth; this done, put it into a kettle, and that on a furnace with a moderate fire, which gradually increaſe till it begins to ſmoke, evaporate, loſe its humidity, and grow very white: it muſt be kept continually ſtirring with a ladle, for fear it ſhould return to its former figure, whereby its greaſineſs will be taken away; after that, ſo much water is to be poured into the kettle as will cover the nitre; and when it is diſſolved, and reduced to the conſiſtency of a thick liquor, it muſt be ſtirred with a ladle without intermiſſion, till all the moiſture is again evaporated, and it be reduced to a dry and white meal. See the ſequel of this article, and Nitrat *of Potaſh*.

The like regard is to be had to the ſulphur, chooſing that which is in large lumps, clear and perfectly yellow; not very hard, nor compact, but porous; nor yet too much ſhining; and if, when ſet on fire, it freely burns away all, leaving little or no reſident matter, it is a ſign of its goodneſs; ſo likewiſe, if it be preſſed between two iron plates that are hot enough to make it run, and in the running appear yellow, and that which remains of a reddiſh colour, it may be concluded to be fit for the purpoſe. But in caſe the ſame be foul and impure, it may be purified in this manner: melt the ſulphur in a large iron ladle, or pot, over a very gentle coal fire, well kindled, but not flaming; then ſcum off all that riſes on the top, and ſwims upon the ſulphur; take it preſently after from the fire, and ſtrain it through a double linen cloth, letting it paſs at leiſure; ſo will it be pure, the groſs filthy matter remaining behind in the cloth. See Sulphur, and ſequel of the article.

For the charcoal, the third ingredient, ſuch ſhould be choſen as is large, clear, and free from knots, well burnt and cleaving. See Charcoal.

The charcoal of light woods has been generally employed; but M. Beaumé affirms, from experience, that the charcoals of heavy and hard woods, if they have been well made, are as fit for the purpoſe. The charcoal not only concurs with the ſulphur in ſupplying the inflammable matter, which cauſes the detonation of the nitre, but alſo conſiderably adds to the explosive power of the detonating nitre, by the quantity of elaſtic vapour expelled during its combuſtion.

Gunpowder being a mixture of ſulphur and charcoal, which are very inflammable ſubſtances, with ſalt-petre, which in itſelf is not, if the ſalt-petre be too much in quantity, when compared with the other two, their burning may not be ſufficient to conſume the whole of the ſalt-petre; whence the fire may be leſs violent, and conſequently the powder leſs vigorous, than if ſome of the ſalt-petre was taken away, and a like quantity of the other materials were added in its ſtead. On the other hand, if the ſalt-petre in the compoſition be leſs than what the burning of the other two ſub-

ſtances can eaſily conſume, the fire will be leſs active than it ought to be, becauſe it is not augmented ſo much as it would be if a larger quantity of ſalt-petre had been added to the compoſition.

Hence it appears, that the goodneſs of powder is not to be eſtimated only from the quantity of ſalt-petre contained in it, although that ſubſtance ſeems to be the baſis of the elaſtic fluid, in which its force conſiſts: for ſince the converting of the ſalt-petre into that fluid, and the elaſticity of the fluid, afterwards, depend in ſome meaſure on the violence of the fire produced at the exploſion, it is plain that there is a certain proportion in the mixture of the materials, which will beſt contribute to this purpoſe, and conſequently to the perfection of the powder.

What this proportion is, has been aſcertained by experience; and it ſeems to be generally agreed, that in any quantity of powder, three-fourths of it ſhould be ſalt-petre, the remaining one-fourth conſiſting of equal quantities of ſulphur and charcoal. This is the proportion followed by the French, and by moſt nations in Europe: we, indeed, pretend to a greater degree of nicety in our proportions; though, it is ſaid, they do not greatly differ from what is here mentioned; nor is it certain that they are preferable: this, however, may be depended on, that no methods of proving powder, hitherto generally practiſed in England, could at all aſcertain the difference; and other powders made with the uſual proportion, are nothing inferior to our's.

But it is not the due proportion of the materials only which is neceſſary to the making of good powder; another circumſtance, not leſs eſſential, is the mixing of them well together; if this be not effectually done, ſome parts of the compoſition will have too much ſalt-petre in them, and others too little; and in either caſe there will be a loſs of ſtrength in the powder. Robins, ubi ſupra, p. 119, &c.

The actual mode of making gunpowder has been deſcribed in a very ſatisfactory manner by Mr. Coleman, of the royal powder mills of Waltham Abbey, in the 9th volume of the Philoſophical Magazine, and cited in Aikin's dictionary. The ingredients are taken in the proportions of 75 of ſalt-petre, 15 of charcoal, and 10 of ſulphur. The ſalt-petre is almoſt wholly that which is brought from the Eaſt Indies, and is refined by ſolution, evaporation, and cryſtallization. (See Nitrat *of Potaſh.*) It is then fuſed in a moderate heat, ſo as to expel the water, but none of the acid. By refining, the ſalt-petre is freed from thoſe deliqueſcent ſalts, which would render it damp by keeping, and thus materially deteriorate it. The ſulphur is ſuch as is imported from Italy and Sicily, which is refined by melting and ſkimming, and if it be impure, by ſublimation. The Engliſh ſulphur requires expenſive proceſſes for purification, which exclude it from our manufactures of gunpowder. The charcoal formerly uſed in this manufacture near London, and which is ſtill uſed in many parts of the world, was prepared in the uſual mode of charring wood, by forming piles of it, covering it with ſods or fern, and allowing it to burn with a ſlow ſmothering flame. But an improvement has been introduced, which ſerves, in a great degree, to conſtitute the ſuperior excellence of Engliſh powder. The wood is cut into billets, about nine inches long and incloſed in iron cylinders, placed horizontally; and thus burnt gradually to a red heat, the fire being continued till the volatile parts are completely expelled, and the wood is thus completely charred. The pyroligneous acid is, however, preſerved for uſe, by collecting it in pipes, that paſs out of the iron cylinder and dip into caſks, in which the acid liquor condenſes. This acid is uſed in calico-printing, chiefly as the baſis of ſome of the iron liquors, and mordants for dark-coloured patterns. The wood, which, previouſly to charring, is barked, is generally either alder or willow, or dog-wood: but the difference of wood is ſaid to be of no eſſential importance, provided that it be perfectly charred. The three ingredients above deſcribed, being duly prepared, are firſt ſeparately ground into fine powder, then mixed in the requiſite proportions, and afterwards committed to the mill for the thorough incorporation of their component parts. The powder-mill is a ſlight wooden building, with a boarded roof, ſo that in caſe of a moderate exploſion, the roof may fly off without difficulty, and in the leaſt injurious direction. Stamping-mills, which were formerly uſed, have been moſtly ſet aſide in our preſent manufactures, on account of the danger of over-heating, and the accidents attending it; and the buſineſs is now performed by two ſtones placed vertically, and running on a bed-ſtone, or trough. About 40 or 50 pounds of the mixed maſs are laid upon this bed-ſtone, and moiſtened with water ſufficient to reduce it, in the proceſs of grinding, to a conſiſtence conſiderably ſtiffer than paſte, which experience aſcertains to be the moſt eligible. The mills are worked either by water or horſes. The compoſition, thus formed, is worked for about ſeven or eight hours, at leaſt, in order to thoroughly incorporate and intermix the ſeveral ingredients, on which the quality of the powder very materially depends. The fine powder manufactured at Battle, in Suſſex, is ſtill worked in large mortars, or ſtamping-mills, with heavy peſtles of lignum vitæ; but only a few pounds of the maſs are wrought at a time. The next operation is that of "Corning," or graining; for which purpoſe it is ſent to the "Corning-houſe." In this operation, which, however, is not eſſential to the manufacture of perfect gunpowder, and is only performed on account of the convenience of uſing it in grains rather than fine duſt, the ſtiff paſte is firſt preſſed into hard lumps, and theſe are put into circular ſieves with parchment bottoms, perforated with holes of different ſizes, and fixed in a frame connected with a horizontal wheel. Each of theſe ſieves is alſo furniſhed with a "runner," or oblate ſpheroid of lignum vitæ, which, being ſet in motion by the action of the wheel, ſqueezes the paſte through the holes of the parchment bottom, forming grains of different ſizes. The grains are then ſorted, and ſeparated from the duſt by ſieves of progreſſive dimenſions. The grains are next "glazed," or hardened, and their rough edges taken off, by putting them into caſks ſomewhat more than half full, which are fixed to the axis of a water-wheel, and by rapidly revolving, they are ſhaken againſt each other and rounded, and at the ſame time they receive a ſlight gloſs or glazing. In this proceſs much duſt is ſeparated from the grains.

The glazing is found to leſſen the force of the powder from a fifth to a fourth (ſee Iriſh Tranſ. ubi ſupra); but it ſerves to preſerve the powder from being injured by damp. When the powder has been corned, duſted, and glazed, it is dried in the "ſtove-houſe," where great care ſhould be taken to avoid exploſion. The ſtove-houſe is a ſquare apartment, three ſides of which are furniſhed with ſhelves or caſes, on proper ſupports, arranged round the room, and the fourth contains a large caſt-iron veſſel, called a "gloom," which projects into the room, and is heated from the outſide, ſo that no part of the fuel may touch the powder. For greater ſecurity againſt ſparks by accidental friction, the glooms are covered with ſheet copper, and are always cool when the powder is put in or taken out of the room. Here the grains are thoroughly dried, loſing in the proceſs what remains of the water added to the mixture in the mill, for bringing it to a working ſtiffneſs. This loſs Mr. Cole-

man finds to be from three to five parts on 100 of the composition. The manufacture of the powder, when it is dry, is completed. The government powder for all sorts of ordnance, as well as for small arms, is usually made at the same time, and always of the same composition; the difference consisting only in the size of the grains, as they are separated by the respective sieves. A method of drying powder by steam-pipes, running round and crossing the apartment, has been successfully tried; and thus the possibility of any injurious accident from over-heating is prevented. The temperature of the room, when heated in the common way by a gloom-stove, is always regulated by a thermometer hung in the door of the stoves.

The powder should not be dried too hastily, or with too great heat; for in this case some of the sulphur sublimes out, (which it will do at a less heat than that which will inflame the powder,) and then the intimate mixture of the ingredients will be destroyed: and besides, the surface of the grain is hardened whilst the inner part is left damp.

Mr. Coleman deduces from experiment the following inferences: *viz.* "that the ingredients of gun-powder only pulverized and mixed have but a very small explosive force: that gunpowder granulated after having been only a short time in the mill, has acquired only a very small portion of its strength, so that its perfection absolutely depends on very long continued and accurate mixture, and incorporation of the ingredients:—that the strength of gunpowder does not depend on granulation, the dust that separates during this process being as strong as the clean grains:—that powder undried is weaker in evey step of the manufacture than when dried:—and lastly, that charcoal made in iron-cylinders, in the way already mentioned, makes much stronger powder than common charcoal. This last circumstance is of so much consequence, and is so fully confirmed by experience, that the charges of powder now used for cannon of all kinds, have been reduced one-third in quantity, when this kind of powder is employed." The barrelling of powder is usually reserved for dry weather, as it is of great importance to avoid moisture.

Count Rumford (see Phil. Trans. vol. lxxi. pt 2.) pursued the following method for determining the specific gravity of gunpowder. A large glass bucket, with a narrow mouth, being suspended to one of the arms of a very nice balance, and exactly counterpoised by weights put in the opposite scale, was filled first with government powder poured in lightly, then with the same powder shaken well together, afterwards with powder and water together, and lastly with water alone, and in each case the contents of the bucket were very exactly weighed. The specific gravity of gunpowder determined by these experiments is as follows:

Specific gravity of rain-water - -	1.000
Government powder, as it lies light in a heap, mixed with air - - - -	0.836
Government powder, well shaken together -	0.937
The solid substance of the powder - -	1.745

Hence it appears, that a cubic inch of government powder shaken well together weighs just 243 grains; that a cubic inch of solid powder would weigh 442 grains; and consequently, that the interstices between the particles of the powder, as it is grained for use, are nearly as great as the spaces which these particles occupy. In his "Essays" the same ingenious philosopher estimates the specific gravity of gunpowder to be about 1.868.

To recover damaged powder, the method of the powder merchants is this; they put part of the powder on a sail-cloth, to which they add an equal weight of what is really good; and with a shovel mingle it well together, dry it in the sun, and barrel it up, keeping it in a dry and proper place.

Others again, if it be very bad, restore it by moistening it with vinegar, water, urine, or brandy; then they beat it fine, searce it, and to every pound of powder add an ounce, an ounce and an half, or two ounces (according as it is decayed) of melted salt-petre; and afterwards these ingredients are to be moistened and mixed well, so that nothing may be discerned in the composition; which may be known by cutting the mass, and then they granulate it as aforesaid.

In case the powder be in a manner quite spoiled, the only way is to extract the salt-petre with water, according to the usual manner, by boiling, filtrating, evaporating, and crystallizing; and then, with fresh sulphur and charcoal, to make it up anew again.

Gunpowder, *Laws relating to.* By an act made in the 16 C. I. c. 21, all subjects may make and sell gunpowder, and bring into the kingdom salt-petre, brimstone, or any other material for the making of it. The erection of powder-mills, or the keeping of powder-magazines near a town, is a nuisance by the common law; for which an indictment or information will lie. By 12 G. III. c. 61, which reduces into one all former acts relating to the making, keeping, and carrying of gunpowder, no person shall use any mill or other engine for the making of gunpowder, in any place except in mills and other places where the manufacturing of gunpowder shall be actually carrying on at the time of the commencement of this act, or where it shall afterwards become lawful to carry on such manufacture by licence for that purpose; on pain of forfeiting all gunpowder otherwise manufactured; and 2*s.* for each pound. Nor under the same penalty shall any person, for the making of gunpowder, use any mill or engine worked with a pestle, commonly called a "Pestle-mill;" nor in any mill or engine make at any one time, under any single pair of mill-stones, any quantity of gunpowder, or materials to be made into gunpowder, exceeding 40*lb*; on pain of forfeiting all above 40*lb.*, and also 2*s.* for each pound. This act does not extend to the powder-mills then erected in the parishes of Battle, Crowhurst, Seddlecombe, and Brede, in the county of Sussex, so far as relates to the making of such fine fowling gunpowder only, as is known by the name of "Battle powder." No person shall dry at any one time, in any one stove, &c. any quantity exceeding 40 *cwt.* on pain of forfeiting all above that weight, and 2*s. per* pound. No person shall keep in any corning-house, drying-house, dusting-house, or other place used in the making of gunpowder, or in any adjoining building, (except magazines or store-houses constructed with stone or brick, and situated, at least, 50 yards from the gunpowder mill,) any greater quantity of gunpowder than shall be necessary for the work then carrying on in such house or other place; on pain of forfeiting all the gunpowder above such necessary quantity, and 2*s.* for each pound. Manufacturers of gunpowder are to provide, besides the magazines and store-houses near their mills, a good and sufficient magazine remote from their respective mills, for the purpose of receiving and keeping all the gunpowder made at such mills, which magazine shall be built with brick or stone, near the river Thames, and below Blackwall, or in some other convenient place to be licensed by the justices; on pain of forfeiture of 25*l.* for every month, during which gunpowder shall be made without such magazine, and 5*l.* for every day during which they shall neglect to remove, with due diligence, the gunpowder made at such mill or adjoining magazine to the magazine so situated remote

from the mill. Every maker of gunpowder, who ſhall keep any charcoal within 20 yards of any mill or engine for the making of gunpowder, or of any drying, corning, or duſting-houſe, or any adjoining magazine or ſtore-houſe belonging to it, ſhall forfeit 5*l.* for every week during which ſuch charcoal ſhall be ſo kept. No perſon, being a dealer in gunpowder, ſhall keep at any one time more than 200*lb.* of gunpowder, and, not being a dealer, more than 50*lb.* in any houſe, &c. within the cities of London or Weſtminſter, or within three miles of either of them; or within any other city, borough, or market town, or one mile thereof; or within two miles of any of the king's palaces, or any of the king's magazines; or half a mile of any pariſh church; or in any other part of Great Britain, except in mills or other places which, at the commencement of this act, ſhall be uſed for the making of gunpowder; on pain of forfeiting all the gunpowder above the quantity allowed to be kept, and the barrels, and alſo 2*s.* for every pound beyond the allowed quantity: provided that it ſhall be lawful for any perſon to keep, for the uſe of any mine or colliery, any quantity, not exceeding 300*lbs.* in any magazine or warehouſe within 200 yards of ſuch mine or colliery. However, it ſhall be lawful for the juſtices in ſeſſions, from time to time, to licenſe the erecting or having ſuch mills and offices, or ſuch magazines for keeping unlimited quantities of gunpowder in places, not being within London or Weſtminſter, or any limits before deſcribed; and the juſtices, upon due application, and by due proceſs of law, which the act ſtates, may be ordered by the court of king's bench to grant ſuch licenſe. No perſon ſhall carry at any one time more than 25 barrels of gunpowder in any waggon, cart, or other carriage by land; or more than 200 barrels in any boat, barge, or veſſel by water, except in veſſels for importation or exportation; and the barrels ſhall be ſo ſecured that no part of the gunpowder ſhall be ſcattered in the paſſage; and each barrel ſhall contain no more than 100*lb.* of gunpowder; and when conveyed by land ſhall be entirely cloſed in a leathern bag, or bags commonly called ſaltpetre bag; and every carriage ſhall be covered with a complete covering of wood, painted cloth, tarpaulin, &c.; and no gunpowder ſhall be carried in any boat, &c. that hath not a cloſe deck, which ſhall be covered with raw hides or tarpaulins; on pain of forfeiture of the gunpowder and barrels, &c. which any perſon may ſeize for his own uſe on conviction of the offender. Juſtices are empowered to iſſue warrants for ſearching, in the day time, any houſe, mill, magazine, &c. or any carriage, ſhip, boat, &c. in which gunpowder is ſuſpected to be made, kept, or carried, contrary to this act; and the ſearcher may ſeize ſuch gunpowder and barrels. For ſecurity of ſhips on the river Thames, no maſter of any outward bound veſſel ſhall receive on board more than 25*lb.* of gunpowder (except for the king's ſervice) before the arrival of ſuch veſſel at or below Blackwall; and the maſter of every veſſel coming into the river Thames ſhall (except in caſe of the king's ſervice) put on ſhore in proper places all the gunpowder on board above 25*lb.*, either before the arrival of ſuch veſſel at Blackwall, or within 24 hours; on pain of forfeiting all the gunpowder above 25 pounds and barrels, and 2*s* for every pound. The proviſions of this act ſhall not extend to any mills or other buildings erected for making gunpowder in any lands belonging to his majeſty, or to the keeping of gunpowder in any of his majeſty's ſtore-houſes or magazines; or to hinder the trial of gunpowder by his majeſty's officers; or to the carriage of gunpowder to or from the king's magazines; under a ſpecial order from the board of ordnance; or to the carriage of gunpowder with forces on their march, or with the militia during their annual exerciſe, or which ſhall be ſent for the uſe of ſuch forces and militia. *

Gunpowder, in *Agriculture*, a material employed by the farmer for the purpoſe of blaſting ſtones, &c. It has been lately found that the expence of this ſubſtance may be greatly leſſened by the mixing of a portion of quick lime with it. See Blasting.

Hammer

HAMMER, an inftrument of iron, with a handle of wood; ufed, in moft mechanic arts, to beat, ftretch, drive, &c. Bodies capable of being ftretched or extended under the hammer, are faid to be *malleable*.

The Latins call it *malleus*, anciently *martulus* or *marculus;* by which name Pliny calls it when he fays that Cyntra, fon of Agrippa, invented the hammer and pincers. Hift. Nat. lib. vii. cap. 56. Vide Hardouin. Not. ad loc.

The hammers of our great forges are moved or worked by a water-mill.

HAMMER, in the *Manege*. See SHOEING-*hammer*.

HAMMER *of a Clock*. See CLOCK.

HAMMER, in *Anatomy*. See MALLEUS and EAR.

HAMMER-*headed fhark*. See SHARK.

HAMMER, *Yellow*, in *Ornithology*. See EMBERIZA *Citrinella*.

HAMMER-*hardened*, in *Smithery*, is faid of iron which is fhort or brittle, owing to its having been hammered when in a warm or due red heat, which is fuppofed to clofe its pores. Hammer-hardened iron, by being heated to a white heat, and fuffered to cool gradually, again recovers its toughnefs. See HARDENING.

HAMMER-*men*, or *Drivers*, in *Mining*, are thofe colliers who fall or wedge down the coals in a coal-pit, after the holers have undermined them, the proceffes of which are defcribed in Mr. Farey's Report on Derbyfhire, vol. i.

HAMMER-*mills*, or *Forges*, in the *Iron Manufacture*, are works in which very large tilt and forge hammers, worked by water-wheels or by fteam engines, are ufed for working the iron, and drawing it out into bars. Smaller hammers of the fame kind are ufed now for forging the articles of various manufactures; in the fcythe factories, thefe are called fkelpers, and are very common in the neighbourhood of Sheffield. The hammer-mill ufed by Mr. George Walby, trowel-maker of Gofwell-ftreet, is on a very curious conftruction; a view and defcription of which may be feen in the Tranfactions of the Society of Arts, vol. xxii. page 335.

HAMMER-*pick*, in *Mining*, is a ftrong pick with a hammer at one end, almoft like that ufed by paviors, which is ufed in coal-pits, by the remblers, or colliers, who break the coals into fizable lumps, after they are fallen by the hammer-men, ready for the hurriers, or thofe who drag them to the fhaft bottom. The whole procefs of working coals is defcribed in Mr. Farey's Report on Derbyfhire, vol. i.

Hardening

HARDENING, the act of communicating a greater degree of hardnefs to a body than it had before.

The hardening and tempering of iron and fteel make a confiderable article in the mechanical arts.

There are divers ways of effecting it: as by the hammer, quenching it when hot, in cold water; cafe-hardening, &c. See TEMPERING and STEEL.

HARDENING, *Hammer*, is moftly ufed on iron and fteel plates, for faws, fprings, rules, &c.

HARDENING, *Cafe*, which is a fuperficial converfion of iron, into fteel (fee CASE-*hardening*) is thus performed: take cow horn or hoof, dry it well in an oven, and beat it to powder; put as much bay-falt as of this powder into ftale urine, or white-wine vinegar, and mix them well together; cover the iron, or fteel, all over with this mixture, and wrap it up in loam, or plate-iron, fo as the mixture touch every part of the work; then put it in the fire, and blow the coals to it, till the whole lump have a blood-red heat, but no higher; laftly, take it out, and quench it. See STEEL, under which article other proceffes for this purpofe are defcribed.

HARDENING *of the ftrata*, in *Geology*, is a point on which theorifts have been much divided: Dr. Hutton, and his commentator, Mr. Playfair, have contended, that fire or heat was neceffary for the confolidation of the ftrata, after their depofit in a foft or pulverulent form, in the depths of the ocean.

Mr. Kirwan fuppofes this hardening to have been in part chemical, and to have followed immediately their depofition, and partly the effect of fubfequent infiltration (Geo. Effays, p. 45.). While others have referred to deficcation or drying, fince the waters retracted, as alone fufficient to account for the hardening of the terreftrial ftrata. Thofe who attentively confider the vaft mafs and fucceffion of different ftrata, which have been explored, below the level of, and even under the coafts of the ocean, as at Newcaftle, Whitehaven, Borrowftownefs, and in Cornwall, &c., will readily perceive, that drying, in its literal fenfe, by expofure to the air, as may be alleged with refpect to the fuperficial ftrata of mountains, and to dry land in general, could have had no part in producing the induration or hardening of thefe fub-marine ftrata, and which, neverthelefs, are found fo exactly fimilar to the parts of the fame ftrata expofed to the air, that the inference feems clear, that to the chemical principles which produced the depofition of the ftrata, is their hardening entirely to be afcribed.

HARDENING *of Timber*. The Venetians are famous for the foundnefs of their fhips, which do not rot as thofe of other nations, but will endure much longer than the others. Tachenius tells us, that the whole fecret of this confifts in the manner of their hardening their timber intended for this fervice; and that this is done by finking it in water while green, and leaving it there many years. This prevents the alkali, or that falt which furnifhes the alkali in burning, from exhaling afterwards; and by this means the timber becomes almoft as incorruptible as ftone. It is evident that the exhaling of this falt, and the rotting of wood, have fome very great connection with one another, fince the more found any piece of timber is, the more falt it proportionably yields; and the wood which is rotten is found on trial to contain no falt at all. Tachen. Hippoc. Chym.

HAT, a covering for the head, worn by the men throughout the western part of Europe.

Hats are chiefly made of hair, wool, &c. worked, fulled, and fashioned to the figure of the head.

Hats are said to have been first seen about the year 1400, at which time they became of use for country wear, riding, &c. F. Daniel relates, that when Charles II. made his public entry into Rouen, in 1449, he had on a hat lined with red velvet, and surmounted with a plume, or tuft of feathers: he adds, that it is from this entry, or at least under this reign, that the use of hats and caps is to be dated, which henceforward began to take place of the chaperoons and hoods that had been worn before. In process of time, from the laity, the clergy also took this part of the habit, but it was looked on as a great abuse, and several regulations were published, forbidding any priest, or religious person, to appear abroad in a hat without coronets, and enjoining them to keep to the use of chaperoons, made of black cloth, with decent coronets; if they were poor, they were at least to have coronets fastened to their hats, and this upon penalty of suspension and excommunication. Indeed, the use of hats is said to have been of a longer standing among the ecclesiastics of Britanny, by two hundred years, and especially among the canons; but these were no other than a kind of caps, and from hence arose the square caps worn in colleges, &c.

Lobineau observes, that a bishop of Dol, in the twelfth century, zealous for good order, allowed the canons alone to wear such hats; enjoining, that if any other person come with them to church, divine service should immediately be suspended. Tom. i. p. 845.

Hats make a very considerable article in commerce: the finest, and those most valued, are made of pure hair of an amphibious animal, called the castor or beaver, frequent in Canada, and other provinces of North America. See Beaver.

Hats, *Method of making.*—Hats, we have observed, are made either of wool, or hair of divers animals, particularly of the castor, hare, rabbit, camel, &c. The process is much the same in all; for which reason we shall content ourselves to instance in that of castors.

The skin of this animal is covered with two kinds of hair; the one long, stiff, glossy, and pretty thin set: this is what renders the skin, or fur, of so much value: the other is short, thick, and soft, which alone is used in hats.

To tear off one of these kinds of hair, and cut the other, the hatters, or rather the women employed for that purpose, make use of two knives, a large one, like a shoe-maker's knife, for the long hair; and a smaller, not unlike a vine-knife, wherewith they shave, or scrape off, the shorter hair.

When the hair is off, they mix the stuff: to one-third of dry castor putting two-thirds of *old coat, i. e.* of hair which has been worn some time by the savages, and card the whole with cards, like those used in the woollen manufactory, only finer; this done, they weigh it, and take more or less, according to the size or thickness of the hat intended. The stuff is now laid on the hurdle, which is a square table, parallel to the horizon, having longitudinal chinks cut through it; on this hurdle, with an instrument called a *bow*, much like that of a violin, but larger, whose string is worked with a little bow-stick, and thus made to play on the furs, they fly and mix together, the dust and filth at the same time passing through the chinks: this they reckon one of the most difficult operations in the whole, on account of the justness required in the hand to make the stuff fall precisely together, and that it may be every where of the same thickness. In lieu of a bow, some hatters make use of a sieve, or searce of hair, through which they pass the stuff.

After this manner they form gores, or two capades, of an oval form, ending in an acute angle at top; and with what stuff remains, they supply and strengthen them in places where they happen to be slenderer than ordinary; though it is to be remembered, that they designedly make them thicker in the brim, near the crown, than towards the circumference, or in the crown itself.

The capades thus finished, they go on to harden them into closer and more consistent flakes by pressing down a *hardening skin* or leather thereon; this done, they are carried to the *bason*, which is a sort of bench with an iron plate fitted therein, and a little fire underneath it; upon which laying one of the hardened capades, sprinkled over with water, and a sort of mould being applied thereon, the heat of the fire, with the water and pressing, imbodies the matter into a slight hairy sort of stuff, or felt; after which, turning up the edges all round the mould, they lay it by, and thus proceed to the other; this finished, the two next are joined together, so as to meet in an angle at the top, and only form one conical cap, after the manner of a manica Hippocratis, or flannel bag.

The hat thus basoned, they remove it to a large kind of receiver or trough, resembling a mill-hopper, going sloping or narrowing down from the edge or rim, to the bottom, which is a copper kettle, filled with water and grounds, kept hot for that purpose. On the descent or sloping side, called the *plank*, the basoned hat, being first dipped in the kettle, is laid, and here they proceed to work it, by rolling and unrolling it again and again, one part after another, first with the hand, and then with a little wooden roller, taking care to dip it from time to time, till at length, by thus full-

ing and thickening it four or five hours, it is reduced to the extent or dimenſions of the hat intended. To ſecure the hands from being injured by this frequent rolling, &c. they uſually guard them with a ſort of thick gloves.

The hat thus wrought, they proceed to give it the proper form, which is done by laying the conical cap on a wooden *block*, of the intended ſize of the crown of the hat, and thus tying it round with a packthread, called a *commander*: after which, with a piece of iron or copper bent for that purpoſe, and called a *ſtamper*, they gradually beat or drive down the commander all round, till it has reached the bottom of the block, and thus is the crown formed; what remains at bottom, below the ſtring, being the brim.

The hat being now ſet to dry, they proceed to *ſinge* it, by holding it over a flare of ſtraw, or the like: then it is *pounced*, or rubbed over with pumice, to take off the coarſer knap; then rubbed over afreſh with ſeal-ſkin to lay the knap a little finer; and laſtly, carded with a fine card to raiſe the fine cotton, with which the hat is afterwards to appear.

Things thus far advanced, the hat is ſet upon its block, and tied about with a packthread as before, to be dyed. The dyer's copper is uſually very large, holding ten or twelve dozen of hats. The dye, or tincture, is made of logwood, verdigris, copperas, and alder-bark; to which ſome add galls and ſumac.

In the manufacture of La Cote d'Or, ſays citizen Chauſſier, (Journal Polytechnique, i. p. 160, &c.) the nut-gall is not uſed, and oak-bark has been ſubſtituted with advantage.

Here the hat is kept boiling for about three quarters of an hour; then taken out and ſet to cool, and then returned to the dye, and this for ten or twelve times ſucceſſively. For the method of dyeing hats, ſee DYEING *of Hats*.

The dye being complete, the hat is returned to the hatter, who proceeds to dry it, by hanging it in the top or roof of a ſtove or oven, at the bottom of which is a charcoal fire; when dry, it is to be ſtiffened, which is done with melted glue or gum ſenegal, applied thereon by firſt ſmearing it, and beating it over with a bruſh, and then rubbing it with the hand. The next thing is to *ſteam* it on the *ſteaming baſon*, which is a little hearth or fire-place, raiſed three feet high with an iron plate laid over it exactly covering the hearth; on this plate they firſt ſpread cloths, which being ſprinkled over with water to ſecure the hat from burning, the hat is placed brim downwards thereon; when moderately hot, the workman ſtrikes gently on the brim with the flat of his hand, to make the joinings incorporate and bind ſo as not to appear; turning it from time to time, this way and that way, and at laſt overturning and ſetting it in the crown.

When ſteamed ſufficiently and dried, they put it again on the block, and bruſh and *iron* it on a table or bench for the purpoſe, called the *ſtall-board*; this they perform with a ſort of irons like thoſe commonly uſed in ironing linen, and heated like them, which being rubbed over and over each part of the hat, with the aſſiſtance of the bruſh, ſmoothens and gives it a gloſs, which is the laſt operation; nothing now remaining but to clip the edges even with ſciſſars, and ſew a lining to the crown.

The ſeveral operations employed in hat-making, are ſeparately deſcribed under the articles FELTING, FULLING, and DYEING, to which the reader is referred. The laſt operation, ſays Chauſſier, (ubi ſupra), conſiſts in lining the inner ſurface of the crown, as well as of the brim of the hat, with a glutinous ſubſtance, which in drying gives firmneſs to the work, and preſerves its form. The uſual compoſition is made of gum arabic, common gum, and Flanders glue, which are diſſolved together in a ſufficient quantity of water, and brought to the requiſite thickneſs by boiling. This preparation, ſimple and eaſy as it appears, is not indifferent with regard to the beauty and duration of the work. If it be too tenacious, it renders the ſtuff dry and brittle, and after ſome months uſe, a kind of greyiſh incruſtation is formed on the ſurface, which alters the texture. "It appeared to me, (ſays Chauſſier), that this effect was cauſed by the gum arabic which is added to the glue. I therefore ſought among the plants of our own country for a ſimple preparation, which might be ſubſtituted inſtead of theſe natural and friable gums. The mucilaginous principle abounds in a great number of plants, and may be eaſily extracted by ebullition; and a gum may even be formed by evaporation, which preſerves its ſuppleneſs and flexibility. Theſe conſiderations induced me to recommend, inſtead of the uſual preparation, a ſolution of glue in a decoction loaded with the mucilage of linſeed oil. This preparation has been long uſed with economy in the manufactory, and with advantage in the excellence of the work. Since that time citizen Margueron having communicated to me his obſervations on the mucilage which may be extracted from the leaves of the horſe-cheſnut tree *(maſronier d'Inde)*, and having aſcertained how great a portion of mucous and adheſive matter theſe leaves afford, eſpecially when the foliation is in its vigour; a ſtrong decoction of theſe leaves has been uſed with much ſucceſs to make the preparation with glue." Our author adds, that there are many other native plants which would be equally proper to afford factitious gums, and of which the uſe would be very advantageous.

HATS, *Laws relating to*. By 24 Geo. III. c. 51, all retailers of hats, commonly called felt or wool, ſtuff or beaver hats, or any leather or japanned hats, ſhall take out a licence from the ſtamp-offices, for which ſhall be paid within the bills, 40*s*., elſewhere 5*s*.; which licence ſhall be renewed annually, ten days before the end of the year. If any retailer ſhall ſell any felt hats without a licence, he ſhall forfeit 50*l*.; and every perſon who ſhall ſell any leſs quantity than one dozen of hats at one time to any one perſon, ſhall be deemed a retailer. Such perſon ſhall put over his door, or in the front of his houſe or ſhop, the words "dealer in hats by retail," on pain of forfeiting 40*s*.; and if an unlicenſed perſon put up theſe words, he ſhall forfeit 50*l*. For every hat ſold by a licenſed retailer ſhall be paid the following duty: *viz*. if not exceeding the value of 4*s*, 3*d*.; above 4*s*. and not exceeding 7*s*., 6*d*.; from 7*s*. to 12*s*., 1*s*.; and above 12*s*., 2*s*. By 36 Geo. III. c. 125, all hats, previous to the delivery of them, ſhall be ſtamped on the lining; however, any licenſed dealer may ſell to any other of the ſame deſcription any unſtamped hats. The penalty for ſelling unſtamped hats is 10*l*.; and for fixing ſtamped linings after they have been uſed, there is a penalty of 10*l*. and the ſame penalty alſo for receiving on ſale, or wearing hats unſtamped. Counterfeiting or forging of ſtamps is a capital felony. By 43 Geo. III. c. 68, for every hat, as above deſcribed, imported, ſhall be paid a duty of 1*l*. 1*s*., and on exportation ſhall be allowed a drawback of 10*s*. 6*d*. For the encouragement of the hat-manufacture, it is enacted by 24 Geo. III. c. 21. that no hare or coney ſkins ſhall be exported on the penalty of 500*l*. and forfeiture of the ſame; and every perſon aſſiſting ſhall forfeit 40*l*. Dyeing ſuch ſkins incurs a forfeiture of the ſame, and of 20*l*. For the further encouragement of the hat-manufacture, all goats' hair or Turkey goats' wool may be imported duty free.

HATS for women have been made in various forms, of ſilk, ſtraw, ſhavings of wood, ivory, feathers, gold, and ſilver.

Hat is alfo figuratively ufed for the dignity of a cardinal, or a promotion to that dignity. In this fenfe they fay, to expect a hat; to claim, or have pretenfion to the hat, &c.

Pope Innocent IV. firft made the hat the fymbol or cognizance of the cardinals; enjoining them to wear a red hat, at all ceremonies and proceffions, as a token of being ready to fpill their blood for Jefus Chrift. See Cardinal.

Hull

HULL, or KINGSTON-UPON-HULL, in *Geography*, a borough, market-town, and sea-port in the East Riding of the county of York, England, is situated on the western side of the river Hull, and the northern bank of the river Humber, at the distance of about 25 miles from the mouth of the latter; nine miles S. of Beverley; 173 N. of London; and 38 S.E. of York. It extends nearly two miles in length, in a direct line, in which extent is included the adjoining parish of Sculcoates; and to rather more than half that distance in a parallel direction towards Beverley. The town originated in the year 1296, under the immediate patronage of king Edward I., who, on his triumphant return from Scotland, projected the foundation of a port, &c. at this place, then a small hamlet, called Wyke, and put his design immediately into execution. Peculiar privileges were granted to builders and residents, together with a royal charter, vesting the government in a warden and the body of freemen; and the new-formed town was distinguished by the appellation of Kingston, or Kingstown-upon-Hull. Edward founded a house of White friars, and caused a hall to be built for his own residence. This was probably given to the De la Poles, for soon afterwards a magnificent manor-house was erected by that wealthy family, which was frequently honoured with the royal presence, and falling to the crown by the attainder of Edmund de la Pole, earl of Suffolk, in 1508, became for some time the residence of king Henry VIII.

So rapid was the progress of the place, that, in about sixty years from its foundation, it was called upon to furnish king Edward III. with 16 ships and 466 men. In Leland's time it was a fair and well built town; and, according to Camden, it possessed stately edifices, strong fortresses, ships well equipped, a number of merchants, and abundance of all kinds of wealth; having been favoured with not less than sixteen charters from various successive monarchs. It was first fortified under a charter from king Edward II., and the walls repaired and strengthened with towers of brick in the time of king Richard II. by sir Michael de la Pole, who appears to have revived in this place the art of brick-making, which had fallen into disuse since the time of the Romans. King Henry VIII. built two block-houses and a citadel on the east bank of the river Hull, at an expense of 23,000*l.*, although he drew great part of the materials from the dissolved houses of Black and White friars, and the church of St. Mary. King Charles II., in 1681, laid out a vast sum in improving the fortifications, which had suffered considerably from the severe siege of the town by the earl of Newcastle, and during the civil wars in the preceding reign. Within the last 35 years, the whole of these ancient works of defence, with the gates of the town, have been demolished, except two of the fortresses built by Henry, which, being guarded by several batteries and modern erections, are now converted into magazines, capable of containing more than 20,000 stand of arms, and ordnance stores for twelve or fifteen sail of the line, defended by a regular garrison,

Hull consists of three principal divisions, formed by the intervention of the docks, which, occupying the greater part of the space where the walls formerly stood, nearly insulate the old town. That on the north side of the old dock is in the parish of Sculcoates; all its buildings have been erected within the last thirty years, and form several spacious and handsome streets. A neat hall has been built for the administration of justice, &c. this part of the town being in the county of York, and not under the jurisdiction of the magistrates of Hull. The other division has arisen still more recently, and lies to the west of the Humber dock, occupying the situation of the ancient hamlets of Wyke and Myton; by which latter name it is now distinguished, and is included in the county of the town of Hull. A suburb also has lately sprung up, on the Holderness side of the river, in the parishes of Drypool and Sutton, encompassing the garrison, and connected with the town by a bridge of four stone arches, rebuilt in 1787, with a draw-bridge in the centre, which has this year (1811) been renewed on a very ingenious and novel construction, and is wide enough to admit the largest vessels that have occasion to pass through it. The whole town stands on a level tract of ground, within a short distance of the Yorkshire wolds; the principal streets are broad and well paved, and in lighting and watching it is not inferior to any place in the kingdom. A few years ago, it was computed that about 200 houses were built annually, but since the interruption to the Baltic trade, the principal source of revenue to this port, that number has been much diminished.

The edifices for religious worship belonging to the establishment are two parish churches, that of the Holy Trinity and St. Mary's; with a chapel of ease, and the chapels of the Trinity-house and Charter-house. The church of the Holy Trinity, a noble structure, was first erected in the reign of king Edward II.; the tower and west end were added about the time of king Henry VII., by whose successor, Hull

was made the see of a suffragan bishop, who possessed a stately palace in the High-street, long since destroyed. The church, however, remained under that of the neighbouring village of Hesle, until separated by an act of parliament in 1661. St. Mary's was formerly a much larger structure, and belonged to the priory of Ferriby. Great part of it, including the steeple, was pulled down by king Henry VIII. as obstructing the view from his palace. St. John's is a chapel of ease to the Holy Trinity, and was finished in 1792 at the sole expense of the Rev. Thomas Dikes, LL.B. the present incumbent. There are also various meeting-houses for the peculiar doctrines and worship of all the prevailing sects.

The charitable institutions in Hull are numerous. The most ancient and splendid is that of the Trinity-house, founded by subscription in 1369, and rebuilt in 1753: its funds have been progressively augmented by legacies and benefactions. It was incorporated by letters patent in the reign of Henry VI.; and its charters and grants have, at various subsequent periods, been renewed and extended. The fund is considerably increased by a monthly contribution of sixpence from every seaman sailing from this port; when superannuated, or disabled, they obtain relief, as do also their widows and children, from this charity. Several distinguished characters have been admitted to the freedom of this corporation, which is governed by wardens, brethren, and assistants. In a marine-school, connected with it, thirty-six boys are, for three years, clothed and educated for the sea service; the guild also provides North sea pilots for the royal navy, when required by government. The Charter-house hospital is worthy of particular notice; it was founded, together with an adjoining priory, by Michael de la Pole, for the support of a certain number of pensioners, denominated brothers and sisters; under the superintendance of a master, who enjoys a salary of 100*l.* per ann., with a house and garden. Several other smaller hospitals, for similar purposes, are distinguished by the names of the respective founders, *viz.* Lister's, Gregg's, Crowle's, Watson's, (bishop of St. David's,) Gee's, Harrison's, Ratcliff's, and Weaver hospitals. The workhouse is a large building, commonly known by the name of Charity hall. For the relief of the indigent sick and maimed, a general infirmary was erected, in 1782, by voluntary contributions, on a plan superior to most establishments of the kind, which has been the means of restoring to health near 9000 persons. Here are likewise a free grammar-school, founded by Alcock, bishop of Ely, in 1486, which enjoyed considerable reputation, especially under its late master the Rev. Jos. Milner, A.M.; the Vicar's-school, established by the Rev. W. Mason, father of the poet of that name; a school for girls, and a valuable institution for putting out poor boys apprentices, endowed by Ald. Coggan, and another for orphans, endowed by Ald. Ferris. Two handsome buildings have also been recently erected, capable of containing 500 boys, and 250 girls, who are instructed with great success, according to the improved system of education. The chief part of the expense, as also that of several Sunday-schools and other charities, is defrayed by voluntary subscriptions.

Besides the various buildings already noticed, there are the custom-house, intended originally as an exchange also, but having been long disused for that purpose, the present comfortable room, with a news-room over it, was designed and executed in 1794, by and at the expense of an individual, though with a view to his ultimate advantage; the assembly rooms, not now adequate to the wants and opulence of the town; the gaol; the Neptune hotel; the Rodney and Minerva lodges of Free-masons, the former of which is a most elegant and handsome room; the subscription libraryt, founded in 1775, and built in 1800, a great advantage to the inhabitants, and containing many thousand volumes; and the theatre royal, rebuilt in 1809, a spacious and convenient structure, the interior of which is fitted up in a superior style of comfort and elegance. The avenue from the market-place to the Humber was lately widened, by taking down the guild hall, a mean brick building, and on its scite shambles were erected, which, for convenience, elegance, and ventilation, may challenge comparison with any in the kingdom. The old shambles being likewise removed, the beautiful east end of Trinity church is again thrown open to the market-place, in the centre of which stands an equestrian statue of king William III. erected in 1734. Until a new guild hall shall be provided, the corporation transact business in a large house fitted up for the purpose. Among the public accommodations enjoyed by the inhabitants, may be reckoned the Barton-boats, which cross the Humber every tide, to and from Barton, a distance of about seven miles.

The commerce of Hull will be best appreciated by a statement of the annual exports and imports for a few years. The tonnage of this port was, several years ago, inferior only to that of London, Liverpool, and Bristol; its customs only to those of the former two. It sends at present nearly thrice as many ships to the whale fisheries as London, and, exclusive of the latter port, more than all Great Britain besides. Its facilities of communication with the interior, by means of the Ouse and Trent, and the canals communicating with them are very great. The gross amount of the customs was

		£.
In 1802	-	438,459
— 1803	-	379,675
— 1804	-	287,210
— 1805	-	386,070
— 1806	-	374,907
— 1807	-	340,825
— 1808	-	198,487
— 1809	-	276,811
— 1810	-	311,780

The number of ships (British and foreign) that entered inwards, and cleared outwards, from and to foreign parts, also of coasting-vessels, was,

	With Cargoes.		In Ballast.		Coasting Vessels.	
	Inwards.	Outwards.	Inwards.	Outwards.	Inwards.	Outwards.
1804	728	279	51	380	1560	1547
1805	658	232	47	327	1626	1602
1806	513	226	29	272	1576	1636
1807	525	158	9	335	1484	1614
1808	207	67	109	135	1557	1733
1809	473	256	55	223	1806	1938
1810	622	193	30	427	1786	2033

The dock was undertaken, according to act of parliament, in 1774, and completed within four years; the entrance is immediately from the river Hull; it extends in length about 600 yards; in width 85; and is 23 feet deep; is capable of containing 100 sail of square rigged vessels; and, with the wharfs and quay, occupies a space of more than thirteen acres; containing in the dock 48,188 square yards, in the quay 17,479; exceeding in capacity the largest in Liverpool, and now only surpassed by those of London: when made it was the largest in the kingdom. The subscribers to the dock are incorporated by the title of "The Dock Company at Kingston-upon-Hull." The original number of shares

was 120, but the trade of the port requiring further accommodation, two other acts of parliament were obtained in 1802 and 1805, by which the company was empowered to increaſe them to 180, the money ariſing from which, amounting to 82,390*l.*, was appropriated to the making of a new dock, which was completed under the title of the Humber dock, in 1809, at an expenſe of 220,000*l.* It opens into the Humber by a lock of excellent workmanſhip, large enough to admit a fifty-gun ſhip, croſſed by an iron bridge in two parts, of very ingenious mechaniſm. The area of the dock and quays is ten acres, with a baſin of four acres; its length 300 yards, width 114, and depth 29 feet; and it is intended to communicate with the old dock at ſome future time, which, when effected, will wholly inſulate the old town. The company is entitled to certain duties on all ſhips entering the port; the profit divided on the ſhares was,

	£.		d.	£.	s.	d.	
In 1805	14,733		0	98	4	6	per ſhare.
— 1806	8,901		0	49	9	1	——
— 1807	8,290		0	46	1	2	——
— 1808	4,941		0	27	9	1	——
— 1809	7,872		0	43	14	9	——
— 1810	10,306	10	0	57	5	-	

The manufactures of Hull are various and extenſive; one of the principal branches is that of expreſſing and refining oil from linſeed, and preparing the reſidue for feeding cattle: the proceſs is chiefly effected by mills worked by the wind. The largeſt and fineſt mills in the kingdom of this kind, both for the above purpoſe and for grinding corn, are to be found in great numbers near this town; their machinery is excellent, and many of them are from 80 to upwards of 100 feet in height. An iron-foundery, two large ſugar-houſes, an extenſive ſoap, and ſeveral white lead manufactories, Greenland yards, numerous dry-docks, ſhipbuilders' yards, and rope-walks, where a great number of hands are conſtantly employed; and ſeveral large breweries are amongſt the moſt important, but do not comprize half the manufactories now exiſting in the town.

The entire civil authority over the town, and the ſeveral places within what is denominated the county of the town of Kingſton-upon-Hull, a diſtrict of more than eighteen miles in circumference, weſt of it, is, by various royal charters, particularly thoſe of king Henry VI. and king Charles II., veſted in the corporation, which now conſiſts of the mayor, the recorder, twelve aldermen, the ſheriff, two chamberlains, a town clerk, a water-bailiff, and other officers, beſides a high ſteward, who is generally ſome nobleman of rank. The mayor is admiral of the Humber, and poſſeſſed of the power of life and death over criminals within his juriſdiction. The judges of aſſize viſited this town, but of late years this has been diſcontinued, and all trials are removed to York, though cauſing a great additional expenſe to thoſe concerned.

Hull returns two repreſentatives to parliament: the right of election of whom, as well as of the ſeveral principal members of the corporate body, except the recorder and high ſteward, is veſted ſolely in the burgeſſes or freemen of the town, an important body, amounting to upwards of 2000. The population returns to parliament in 1801, ſpecified, that the town and county contained 4767 houſes, occupied by 29,516 perſons, of whom 13,051 were males, and 16,465 females: this does not include the adjoining populous pariſh of Sculcoates, nor the ſuburb on the eaſt of the river Hull. A fair is held annually in October, and the markets are abundantly ſupplied, eſpecially when the tide ſuits for the Lincolnſhire farmers to croſs the Humber, on Tueſdays, Fridays, and Saturdays.

Hull has, at different times, given birth to men diſtinguiſhed on various accounts. In the firſt rank muſt be placed her repreſentative in parliament, that incorruptible patriot, Andrew Marvell, whoſe father was lecturer of Trinity church; and, in later times, a moſt worthy man and excellent poet, the Rev. W. Maſon, A.M. ſon of the late vicar of the ſame. It likewiſe gave the titles of earl and duke, both now extinct, to the family of Pierrepoint.

The village of Sculcoates, though not in the county, may juſtly be conſidered as forming a part of the town of Hull; a portion of the old dock is included within it. The church, ſituated towards the northern extremity of the pariſh, is a neat uniform ſtructure, rebuilt in the year 1760, and contains ſome fragments brought from the neighbouring abbey of Meaux.

HULL *River*, in the Eaſt Riding of Yorkſhire, is a ſmall river, which falls into the Humber at the town of Kingſton-upon-Hull, better known by the name of *Hull* only, and as being the fourth ſea-port in point of importance in the Britiſh dominions. The Hull is made navigable from the Humber, about twelve miles, to Aike-beck mouth, the entrance of the Driffield navigation. See CANAL.

HULL *and Leven Canal*, is an inland navigation in Yorkſhire, Eaſt Riding, made in purſuance of acts of parliament obtained in 1801 and 1805; it extends about three miles from the Hull river up to the town of Leven. See CANAL.

Hundreds

Hundreds, in the conſtruction of reeds for weavers, denote the number of diviſions in any given length of the reed. A thorough knowledge of the adaptation of yarn of a proper degree of fineneſs to any given meaſure of reed conſtitutes one of the principal arts of the manufacturer of cloth, as upon this depends entirely the appearance, and in a great degree the durability of the cloth when finiſhed. The art of performing this properly is known by the names of *examining*, *ſetting*, or *ſleying*, which are uſed indiſcriminately, and mean exactly the ſame thing. The reed conſiſts of two parallel pieces of wood of any given length, as a yard, a yard and quarter, &c. The diviſions of the yard being into halves, quarters, eighths and ſixteenths, the breadth of a web is generally expreſſed by a vulgar fraction, as $\frac{3}{4}$, $\frac{4}{4}$, $\frac{5}{4}$, $\frac{6}{4}$, and the ſubdiviſions by the eighths or ſixteenths or *nails*, as they are uſually called, as $\frac{7}{8}$, $\frac{9}{8}$, $\frac{10}{8}$, &c. or $\frac{13}{16}$, $\frac{15}{16}$, $\frac{19}{16}$, &c. In Scotland the ſplits of cane which paſs between the longitudinal pieces or ribs of the reed are expreſſed by hundred porters or ſplits. The porter is 20 ſplits, or $\frac{1}{5}$th of an hundred. In Lancaſhire, Cheſhire, and the other manufacturing counties of England, the diviſions of the reed are different. A comparative table of the differences by which they are reduced, to the ſame ſtandard as nearly as is poſſible, that is to ſay, within one ſplit or diviſion by which the Scotch or Engliſh manufacturer may at one glance aſcertain the relation which the other modes of counting reeds bear to his own, is annexed to this article. In counting reeds by the number of hundreds in a determinate length, which is common to the manufacturers of the continent, as well as to thoſe of Scotland, different lengths are uſed for the ſtandard of fineneſs. In that part of France ſituated around Cambray, which is, or was, the principal ſeat of the cambric manufacture, the ſtandard length of a reed, by which the fineneſs of the ſplits is aſcertained, is 34 inches. In Holland, where the heavier fabrics of linen are chiefly produced, the ſtandard of meaſure is 40 inches, and in Scotland the ſtandard is 37 inches, or the Scottiſh ell. Now it is plain, that if 2000 or twenty hundred diviſions or ſplits be contained in each of theſe reſpective meaſures, thoſe which are contained in 34 inches muſt be finer and cloſer than thoſe contained in 37, and ſtill more ſo than thoſe contained in 40. For the practical purpoſes of manufacture in this country it can be of little importance to aſcertain with preciſion the relative proportions which theſe ſtandards bear to each other, but to the wholeſale purchaſer it muſt be uſeful to have ſome correct idea of the mode by which both the value and quality of the commodity which he purchaſes may be aſcertained with conſiderable preciſion merely by inſpection.

In Lancaſhire and Cheſhire a different mode is adopted both as to the meaſure and diviſions of the reed. The Mancheſter and Bolton reeds are counted by the number of ſplits, or, as they are there called, dents contained in $24\frac{1}{2}$ inches of the reed. Theſe dents, inſtead of being arranged in hundreds, porters, and ſplits, as in Scotland, are calculated by what is there termed *bares* or *bears*, each containing 20 dents, or the ſame number as the porter in the Scotch reeds. Formerly the number of dents in a *bare* was frequently 19, a number ſo ill calculated for any eaſy arithmetical calculation, that it is difficult to conjecture the cauſes which could have ſuggeſted its adoption, unleſs we ſuppoſe that the number 19, in place of 20, was adopted to leave room for the ſhrinking-in breadth when firſt immerſed in any liquid, to which all newly woven cloth is liable. The Cheſhire or Stockport reeds again receive their deſignation from the number of ends or threads contained in one inch, two ends being allowed for every *dent*, that being the almoſt univerſal number in every ſpecies and deſcription of plain cloth, according to the modern practice of weaving, and alſo for a great proportion of the fanciful articles. The number of threads in the warp of a web is generally aſcertained with conſiderable preciſion by means of a ſmall magnifying glaſs fitted into a ſocket of braſs, under which is drilled a ſmall round hole in the bottom plate of the ſtandard, the number of threads viſible in this perforation aſcertaining the number of threads in the ſtandard meaſure of the reed. Thoſe uſed in Scotland have ſometimes four perforations over any one of which the glaſs may be ſhifted. The firſt perforation is $\frac{1}{4}$ of an inch in diameter, and is therefore well adapted to the Stockport mode of counting, that is to ſay, for aſcertaining the number of ends or threads per inch. The ſecond is adapted for the Holland reed, being $\frac{1}{200}$dth part of 40 inches. The third is $\frac{1}{200}$dth of 37 inches, and is adapted for the now almoſt univerſal conſtruction of Scotch reeds, and the fourth, being $\frac{1}{200}$dth of 34 inches, is intended for the French cambrics. Every thread appearing in theſe reſpective meaſures, of courſe, repreſents 200 threads or 100 ſplits in the ſtandard breadth, and thus the quality of the fabric may be aſcertained with conſiderable preciſion, even after the cloth has undergone repeated wettings, either at the bleaching ground or dye work. By counting the other way, the proportion which the woof bears to the warp is alſo known, and this forms the chief uſe of the glaſs to the manufacturer and operative weaver, both of whom are previouſly acquainted with the exact meaſure of the reed.

Comparative Table of 37-inch reeds, being the ſtandard uſed throughout Europe, for linens, with the Lancaſhire and Cheſhire reeds, and the foreign reeds uſed for Holland and cambric.

Scotch.	Lanca-ſhire.	Cheſhire.	Dutch Holland.	French Cambric.
600	20	34	550	653
700	24	38	650	761
800	26	44	740	870
900	30	50	832	979
1000	34	54	925	1089
1100	36	60	1014	1197
1200	40	64	1110	1300
1300	42	70	1202	1414
1400	46	76	1295	1464
1500	50	80	1387	1602
1600	52	86	1480	1752
1700	56	92	1571	1820
1800	58	96	1665	1958
1900	62	104	1757	2067
2000	66	110	1850	2176

In the above table the 37-inch reed is placed firſt. It is called Scotch, not becauſe it either originated, or is excluſively uſed, in that country. It is the general linen reed of all Europe, but in Scotland it has alſo been adopted as the regulator of her cotton manufactures. In the table it is only compared with the neareſt Engliſh reed actually in uſe, for in moſt caſes there is ſome ſmall difference, which, however, is not material for practical purpoſes. For the Holland and cambric reeds, the exact number of ſplits or dents is given merely for compariſon, as theſe reeds are not at all uſed in Britain.

The art of proportioning the yarn to the reeds, for different fabrics, has been always regulated by the practical experience of the manufacturer, and the taſte or fancy of his cuſtomers. Some attempts have been made to reduce it to a ſtandard, and it is evidently a matter of no difficulty. Without analyzing particularly the plans which have been propoſed, and the arguments for and againſt each of them, it ſeems that the following may, in general, be taken as a good approximation.

Every ſpecies of yarn uſed in the manufacture of cloth, may be aſſumed to be a cylindrical body of ſtuff of a certain diameter. Now as the area of every circle is as the ſquare of its diameter, and as the cubical content of every cylinder is found by multiplying the area of its baſe by its height, we may reaſonably infer, that if the diameter of a thread is ſquared, and that ſquare multiplied by its length, it will give the ſolid content, and *vice verſâ;* that the ſquare root of the number which aſcertains the weight of yarn, is a ſymbol of its diameter. If this be granted, it follows, that when any particular denomination of yarn is found to produce a proper fabric of cloth when woven in a reed of any given dimenſion, the proper denomination for any other reed may be found. Or if the yarn is at hand, and the proper reed wanted, it may be found by exactly the converſe of the former analogy. Upon this hypotheſis the analogy will be

As the ſquare root of the given yarn,
Is to the given dimenſions of the reed;
So is the ſquare root of another kind,
To the dimenſions of the reed required.

But as few practical manufacturers or weavers are accuſtomed to the extraction of roots, the real deſcription of the yarn may be taken, and the reed ſquared, or multiplied into itſelf, which will give exactly the ſame reſult. It may be neceſſary to obſerve, however, in this place, that as the fineneſs of cotton yarn is aſcertained by progreſſive numbers; and that of moſt other kinds of yarn, by the weight of certain quantities, the proportion or analogy in the former caſe muſt be direct, and in the latter inverſe, becauſe a diminution of weight in a given quantity neceſſarily implies an increaſe of fineneſs. The two following examples will, it is hoped, render this ſufficiently obvious.

If a manufacturer finds, by experience, that a fabric of goods, ſuch as pleaſe his cuſtomers, is produced by weaving N° 60 of cotton yarn in a reed of 1200 by the linen or Scotch reed, and wiſhes to aſcertain what deſcription of yarn he ought to employ for a web to be woven in a 1500 reed; the proportion will be

As 144, the ſquare of the 1200 reed,
Is to 60, the number of the given yarn,
So is 225, the ſquare of the 1500 reed,
To 94, the neareſt integral number by calculation.

In the converſe he would find the ſquare of the reed, and would ſtill find extraction of the root neceſſary.

But if a manufacturer of linen finds that a fabric of yarn, of any number of ounces to the ſpindle, is well adapted to a 1200 reed, and wiſhes to aſcertain the weight or denomination of yarn fit for a 1500 reed as before, his proportion muſt be inverted.

The chief objection which practical men are apt to make to the above theory of adaptation, which is perhaps the beſt that has hitherto been found, is the following. That in finer fabrics of goods it is not found to produce the deſired effect, and that experience proves, that were a practical manufacturer of cloth to adopt this rule implicitly, either his fine goods would be wanting in that ſhow and elegance which is their chief recommendation, or that his coarſe articles would be flimſy and deficient both in warmth and durability. Allowing to this objection, which is unqueſtionably well founded, in ſome reſpects, all the weight which it deſerves, the anſwer to it is very eaſy. The chief recommendations of coarſe goods are thickneſs and ſtrength, thoſe of fine goods lightneſs and elegance. Theſe are not, nor can be regulated by any exact mathematical rule, as they are much dependant on fancy. No lady would expect, in a fine dreſs, the ſtrength and durability of a ſack, nor would any miller ſtore his flour in a bag, poſſeſſing the principal requiſites of a ſieve. It is ſufficient, if the manufacturer is enabled to obtain a fair proportion for the real fabric, and this he muſt afterwards vary, to ſuit his goods to the market for which they are intended.

Japanning

JAPANNING, the art of varniſhing, and drawing figures on wood, &c. after the ſame manner as the workmen do who are natives of Japan.

The varniſh made and uſed in China and Japan is compoſed of turpentine, and a curious ſort of oil they have. This they mix and boil up to a proper conſiſtence, and this never cauſes any ſwelling in the hands or face of the people who uſe it. The ſwellings in theſe parts, which often happen to thoſe who work the lacquered ware, and ſometimes to thoſe who only paſs by the ſhops of theſe people, is from the lack, and not the varniſh. This lack is the ſap or juice of a tree, which runs ſlowly out on cutting the lower part of the trunk of the tree, and is received in pots ſet on purpoſe under the inciſions. The juice, as it flows from the tree, is of the colour and conſiſtence of cream; and as it comes in contact with the external air, its ſurface becomes black. As they only uſe it when black, their method of preparing it is to ſet it out in the open air, in large flat bowls, in which it looks all ſurface; but that the whole may be of the ſame uniform colour, they continually ſtir it for twenty-four hours together, with a ſmooth piece of iron. By this means the whole becomes thicker than it was before, and of a fine deep black. When it is in this ſtate, they powder ſome burnt boughs of trees, and mix them thoroughly with it; and then ſpreading it thin over any board which they intend to japan, it is ſoon dried in the ſun, and is then abſolutely harder than the board it is laid on. When this is thoroughly dry, they poliſh it over with a ſmooth ſtone and water, till it is as ſmooth as glaſs; and then wiping it very dry, they lay on the varniſh, made of oil and turpentine, and boiled to a proper conſiſtence for this kind of work.

If the work is to be of any other colour than black, that colour is to be mixed with the varniſh, and then the whole ſpread on very thinly and evenly; for on this laying it on depends the principal art of varniſhing. When there are to be figures in gold and ſilver, theſe muſt be traced out with a pencil in the varniſh over the reſt of the work; and when this varniſh is almoſt dry, the leaf-gold or leaf-ſilver is

to be laid on, and polifhed afterwards with any fmooth fubftance.

The fubftances which admit of being japanned are almoft thofe of every kind that are dry, and not too flexible; as wood, metals, leather, and paper prepared. Wood and metals require no other preparation, except that of cleaning their furfaces, and rendering them perfectly even. But leather fhould be fecurely ftrained either on frames or on boards; and paper fhould be treated in the fame manner, and have a previous ftrong coat of fome kind of fize; but it is rarely made the fubject of japanning, till it is converted into *papier maché*, or wrought, by other means, into an inflexible form. One principal variation in the manner of japanning is the ufing or omitting any priming or under-coat on the work to be japanned. In the older practice, fuch priming was always ufed; and is at prefent retained in the French manner of japanning coaches and fnuff-boxes of the *papier maché*. But in the Birmingham manufacture it has always been rejected. The advantages attending the ufe of fuch priming are, that it makes a faving in the quantity of varnifh neceffary to be ufed, and that it helps to form, by means of rubbing and water-polifhing, an even furface for the varnifh. However, when an under-coat of fize is ufed, the japan coats of varnifh and colour will be always liable to crack and peel off, and are lefs durable than thofe which are formed without fuch priming. This difference is obfervable in comparing the wear of the Paris and Birmingham fnuff-boxes.

The laying in of the colours in varnifh or oil inftead of gum-water, is another variation from the method of japanning formerly practifed. But if the colours are tempered with the ftrongeft ifinglafs fize and honey, inftead of gum-water, and laid on very flat and even, the work will not be much inferior in appearance to that done by the other method, and will laft as long as the common old japan work, the beft kinds of the true japan excepted. The proper japan grounds are either fuch as are formed by the varnifh and colour, where the whole is to remain of one fimple colour; or by the varnifh, either coloured, or without colour, on which fome painting, or other decoration, is afterwards to be laid. The priming, or under-coat, which is fometimes ufed in japanning, is of the fame nature with that called clear-coating, practifed by the houfe-painters; and confifts in laying on and drying in the moft even manner a compofition of fize and whiting. The common fize, (fee SIZE,) has been generally ufed; but in nicer works, the glovers or the parchment fize, improved by adding a third of ifinglafs, will be preferable. The work fhould be prepared for this priming, by being well fmoothed with fifh-fkin, or the glafs-fhaver; and by being brufhed over once or twice with hot fize diluted, when it is of the common ftrength, with two-thirds of water. The priming, formed of a fize whofe confiftence is between that of the common kind and glue, mixed with as much whiting as will give it a fufficient body of colour to hide the furface on which it is laid, fhould be laid on evenly with a brufh. Two coats of this priming will generally be fufficient; but if, upon trial with a fine wet rag, it will not receive a proper water-polifh, another coat or more muft be given it. And after the laft coat but one is dry, the work fhould be fmoothed by rubbing it with the Dutch rufhes. When the laft coat is dry, the water-polifh fhould be given, by paffing over every part of it with a fine rag, a little moiftened, till the whole appears perfectly plain and even. The work is then ready to receive the painting or coloured varnifh.

When wood or leather is to be japanned, without priming, it may be prepared by laying on two or three coats of coarfe varnifh, made by diffolving two ounces of feed-lac, and as much rofin, in one pint of rectified fpirit of wine: and then the proper japan-ground muft be laid on. As metals never require to be under-coated with whiting, they muft generally be treated in the fame manner as wood or leather.

For white japan grounds.—Prepare a white varnifh, by working and grinding flake white, or white lead, with a fixth part of its weight of ftarch, and drying the mixture; then temper it into a confiftence fit for fpreading with maftic varnifh, (fee VARNISH,) or compound it with gum anime; lay this on the body to be japanned, previoufly prepared with or without the under-coat of whiting: and varnifh it over with five or fix coats of the following varnifh, formed by diffolving two ounces of the cleareft and whiteft grains of feed-lac, and three ounces of gum anime, pulverized, in about a quart of fpirit of wine, and ftraining off the clear varnifh.

A very good varnifh, free from brittlenefs, may be obtained by diffolving as much gum anime as the oil will take in old nut or poppy oil, boiled gently when the gum is put into it. The ground of white colour may be laid on in this varnifh, and then a coat or two of it may be put over the ground; but it muft be well diluted with oil of turpentine when it is ufed.

Blue japan grounds may be formed of bright Pruffian blue; or of verditer glazed over with Pruffian blue, or fmalt. The colour may be beft mixed with fhell-lac varnifh, and brought to a polifhing ftate by five or fix coats of varnifh of feed lac. But when a bright blue is required, and a lefs degree of hardnefs can be difpenfed with, the method before directed, in the cafe of white grounds, muft be purfued.

Red japan grounds.—For a fcarlet ground, vermilion may be ufed: but this is lefs beautiful than the crimfon produced by glazing it over with carmine or fine lake, or rofe-pink. For a very bright crimfon; inftead of glazing with carmine, the Indian lake, called fafflower, fhould be ufed, diffolved in the fpirit of which the varnifh is compounded. But in this cafe, inftead of glazing with the fhell-lac varnifh, the upper or polifhing coats need only be ufed; which will render this a cheaper method than the ufing of carmine. If the higheft degree of brightnefs be required, the white varnifhes muft be ufed.

Yellow japan grounds.—For bright yellow grounds, king's yellow, or turpeth mineral fhould be ufed, either by themfelves, or mixed with fine Dutch pink. The effect may be ftill more heightened by diffolving powdered turmeric root in the fpirit of wine, of which the upper or polifhing coat is made; which fpirit of wine muft be ftrained off from the dregs, before the feed-lac be added to it for forming the varnifh.

Yellow grounds may likewife be formed of the Dutch pink only.

Green japan grounds may be produced by mixing king's yellow and bright Pruffian blue; or turpeth mineral and Pruffian blue. A cheap, but fouler kind may be had from verdigris with a little of the fore-mentioned yellows, or Dutch pink. But if a very bright green be wanted, the cryftals of verdigris, called diftilled verdigris, fhould be ufed, and their effect will be heightened by laying them on a ground of leaf-gold. Any of thefe may be ufed with good feed-lac varnifh, but will be brighter with the white varnifh.

Orange-coloured japan grounds may be formed by mixing vermilion or red lead with king's yellow, or Dutch pink: or orange lake, or red orpiment will make a brighter orange ground than can be produced by any mixture.

Purple japan grounds may be produced by the mixture of

lake and Pruſſian blue; or a fouler kind, by vermilion and Pruſſian blue.

Black japan grounds may be formed, without heat, by either ivory-black, or lamp-black, which may be laid on with the ſhell-lac varniſh: and the upper or poliſhing coat may be common ſeed-lac varniſh.

For forming the common *black japan grounds* on iron or copper by means of heat, the work muſt be firſt painted over with drying oil, and a little lamp black; and when it is moderately dry, put into a ſtove of ſuch a degree of heat, as will change the oil black, without burning it. The heat ſhould be ſlowly augmented and continued for a long time, in order to harden the coat of japan. This kind of varniſh requires no poliſh.

Tortoiſ[illegible]*s*.—The beſt is made by means of the following varniſh; prepared by boiling together one gallon of good linſeed oil and half a pound of umbre, till the oil becomes very brown and thick; by ſtraining the mixture through a coarſe cloth, and ſetting it again to boil, till it acquires the conſiſtence of pitch. On the piece of work to be japanned, well-cleaned, let vermilion, tempered with ſhell-lac varniſh, or with drying oil diluted with oil of turpentine, be laid thinly on the places deſigned to imitate the more tranſparent parts of the tortoiſe-ſhell.

When the vermilion is dry, bruſh over the whole with the black varniſh, tempered to a due conſiſtence with oil of turpentine; and when it is ſet and firm, put the work into a ſtove, where it may undergo a very ſtrong heat, and be continued for a conſiderable time. This method, propoſed in one of Kunkel's recipes, has been revived in the Birmingham manufactures, where it is purſued in forming the ground of ſnuff-boxes, dreſſing boxes, tea-waiters, &c. This ground may be decorated with painting and gilding in the ſame manner as any other varniſhed ſurface.

Japan-work ought properly to be painted with colours in varniſh. (See PAINTING *in Varniſh* and VARNISH.) The colours are now moſt frequently tempered in oil, having a fourth part of its weight of gum anime previouſly diſſolved in it. This oil ſhould be well diluted with ſpirit of turpentine when it is uſed, that the colours may be laid more evenly and thin, and thus fewer of the poliſhing coats of varniſh will be neceſſary. When water-colours are laid on grounds of gold, ſo as to have the effect of emboſſed work, they are beſt prepared by means of iſinglaſs ſize corrected with honey or ſugar-candy. The body of which the emboſſed work is raiſed may be formed of a very ſtrong gum-water, thickened to a proper conſiſtence by bole armeniac and whiting, in equal parts, which being laid on in the proper figure, and repaired when dry, may be then painted with the proper colours tempered in the iſinglaſs ſize, or in the general way with ſhell-lac varniſh.

The finiſhing part of japanning conſiſts of laying on and poliſhing the outer coats of varniſh. This is in general beſt done with common ſeed-lac varniſh. (See VARNISH.) But where brightneſs is principally regarded, the ſeed-lac muſt give way to the whiter gums. When hardneſs, tenacity, and brightneſs are deſired, the mixed varniſh made of the picked ſeed-lac, already propoſed under *white Japan grounds*, ſhould be adopted. The pieces of work to be varniſhed ſhould be placed near a fire, and made perfectly dry; the varniſh ſhould then be rubbed over them with proper bruſhes; firſt one coat, and when this is dry another ſhould be laid over it; and this operation muſt be continued at leaſt five or ſix times. When a ſufficient number of coats is thus laid on, the work is fit to be poliſhed, which muſt be done, in common caſes, by rubbing it with a rag dipped in tripoli, commonly called rotten-ſtone, finely powdered; but toward the end of the rubbing, a little oil of any kind ſhould be uſed with the powder: and when the work appears ſufficiently bright and gloſſy, the oil alone ſhould be uſed to clear it from the powder, and to give it a brighter luſtre. For white grounds, fine putty or whiting ſhould be uſed inſtead of the tripoli. For gilding of Japan work, ſee *Japanners* GILDING. Handmaid to the Arts, vol. ii. p. 497, &c.

Indigo Mills

INDIGO *Mills*. For the purpofe of effecting the folution and union of indigo with the liquid ufed along with it, for the purpofes of dyeing, mills of various conftructions are in ufe. In this procefs trituration or friction is as much as poffible avoided, and the pulverization is effected merely by bruifing. For this two very fufficient reafons may be affigned; the firft, in point of economy, and the fecond, to avoid chemical inconveniency. On whatever fubftance the indigo was triturated or rubbed, a certain proportion of the ftuff would be mixed or incorporated along with the pulverized indigo, and that proportion of indigo which was abforbed by this ftuff would be either totally loft, or brought into union with another fubftance which might prove ufelefs, and probably injurious in the fubfequent procefs of dyeing. If the former only was the cafe, the abforbed indigo would be totally loft; if the fecond took place, the whole procefs might be utterly fpoiled by the combination. In the appropriate plate, *fig.* 1. reprefents the ground or horizontal plan of fuch an indigo mill as is generally ufed in fmall dye-works, and which is occafionally turned by a man's or boy's hand. This is tedious and laborious, for the operation muft be continued for a very long time before the indigo is fufficiently mixed with the liquid to be fit for ufe, and only a fmall quantity can be put into the veffel at once. *Fig.* 2. is an elevated fection of the fame mill.

In this machine the pulverization or granulation of the indigo is effected by the preffure of a number of fmooth caft-iron balls, like thofe ufed for the fhot of great guns, which, being rolled among the indigo, prefs it into a pafte by their weight, until it unites with the liquid by which it is to be held in folution.

In *fig.* 1, A reprefents the bottom and rim of the veffel which contains the indigo, and which is of a cylindrical form. B is an upright fpindle, which, in this figure, does not appear. Upon the fpindle B is fixed a wheel C C, with a convenient number of arms projecting round the veffel, like the radii of a circle; and below each of thefe arms are projecting pieces of iron, like the pins or teeth of a harrow, for moving the balls. When this wheel C is moved round its axis, the whole balls in the veffel A are fet in motion, and, by rolling over the indigo, gradually prefs it, until it unites with the water or liquid with which it is furrounded. If the bottom of the cylinder be flat, a very fmall part of the furface of each ball can act upon the indigo; but by cafting circular hollow grooves, as reprefented in *fig.* 2, nearly the femi-diameter of the ball will prefs upon the ftuff. The mill is moved by a handle D, *fig.* 2, which fets in motion the fmall bevel wheel E, and this wheel acting upon the horizontal wheel F, fixed upon the fpindle B, fets it alfo in motion, and confequently the wheel C C is moved round its axis, and all the balls roll round upon the indigo. G is a crofs fhaft upon the top of the fpindle B, loaded at each end with a heavy ball. There is generally another fhaft placed at right angles to this, when they affift in regulating and equalizing the motion in the fame manner as any other fly wheel. When the indigo is found to be fufficiently diffolved, and united with the water, the liquid thus formed is drawn off into any other veffel for ufe by means of a vent and fpiggot placed in any convenient part of the bottom of the veffel.

The great labour and time which it requires, and the fmall quantity of ftuff which can be prepared at once by a machine of this kind, renders it ill adapted for the ufe of large works where much indigo is confumed, and where they have generally a horfe-power water-wheel, or fteam-engine, for raifing water, cutting madder, and other purpofes neceffary in extenfive works. *Fig.* 3. reprefents an elevated crofs fection of one of thefe machines, driven by any moving power, and capable of preparing a very great quantity of indigo at all times, as it requires no attendance, excepting to empty the veffel when the indigo is wanted, and add a frefh fupply. H is a femi-circular veffel of caft-iron, placed upon a ftrong wooden frame O, and of any convenient length. I is a cover made in two pieces, with a circular aperture to admit the upright fhaft K working upon the centre, or pivot P. At Q, the upright P is jointed to a horizontal fhaft of wood M, the other end of which is connected by the joint R, with a crank fixed on the end of a horizontal fhaft N driven by the moving power. The circular motion of the fhaft and crank N communicates an alternate, or reciprocating motion, by means of the horizontal connecting fhaft M, to the upper end of the upright fhaft K, which vibrating upon the centre joint P, fets in motion the iron cylinders L, L, in the body of the veffel, which prefs upon the indigo, and produce the fame effect, but to a much greater extent, as the balls in the machine firft defcribed. The cylinders L, L, may be made of any diameter or length which is found convenient. The greater mafs of iron that they contain, the quicker and more effectual will be their operation upon the ftuff, provided there is a fufficient power to drive them. The frame under the joint P extends the whole length of the femi-circular veffel H, which may be any length, according to the extent of the power and quantity of work required. As this machine requires no attention whatever, it is found very ufeful in large dye works, as, by means of it, they can conftantly command a large fupply of prepared indigo, which may be drawn off when wanted, for the longer it is under the preparing procefs, the better in every refpect, and frefh indigo may be added as the fupply gets low.

Ink

INK, a liquor wherewith to write on paper or parchment.

INK, *Printing.* See PRINTING.

INK, *Writing*, is commonly made of copperas and galls, and gum arabic; but other aſtringent plants may ſerve the ſame purpoſe; ſuch as oak-bark, red roſes, logwood, or ſumach. Mr. Boyle ſeems to doubt whether all aſtringent vegetables will do the ſame.

Many are the preparations and methods of compounding the materials for making of writing ink. For many years the ink moſt generally uſed by European writers has been the infuſion of galls and other aſtringent vegetables, containing gallic-acid, rendered black by ſulphate of iron, and thickened by the addition of a little gum or ſugar. This compoſition, however, is liable to fade; but ſince the diſcovery of the method of totally diſcharging the traces of common ink by the application of the oxigenated muriatic acid, more ſerious conſequences are to be apprehended from the univerſal uſe of the common atramentous fluid, than the decay of its colour from age; for it is well known that, while the ſulphate of iron remains on the paper, the colour of the writing may be reſtored by waſhing the MS. with freſh infuſion of galls. We have ſeveral receipts in Nicholſon's Philoſophical Journal, vol. iv. p. 479, 4to., for compoſing ink capable of reſiſting the oxigenated muriatic acid.

Macquer, in the Chemical Dictionary, gives the following receipt for making good ink. In four French pints of common water or beer, let a pound of bruiſed galls be infuſed twenty-four hours without boiling; to this add ſix ounces of gum arabic; and when the gum is diſſolved, ſix ounces of green vitriol, which will ſoon give it the black colour; the liquor is then to be ſtrained through a hair-ſieve.

The following method has been recommended by experience, and is eaſily and ſpeedily practiſed. To a gallon of boiling water, put ſix ounces of blue galls, groſsly pounded, and three ounces of copperas; ſtir the mixture well together, and then add ſix ounces of gum arabic pounded. After ſtirring the whole thoroughly, leave it to ſettle, and the next day ſtrain it off from the dregs for uſe. See IRIS *lutea paluſtris*.

The following compoſition will make a very good black writing ink. Take a gallon of ſoft water, and boil in it a pound of chips of logwood for about half an hour; pour the decoction boiling hot on a pound of the beſt Aleppo galls powdered, and two ounces of pomegranate peels, put into a proper veſſel. After having ſtirred them well together with a wooden ſpatula, place them in the ſunſhine in ſummer, or within the warmth of any fire in winter, for three or four days, ſtirring the mixture occaſionally; then add half a pound of green vitriol powdered, and let the mixture remain four or five days more, occaſionally ſtirring it; and then add four ounces of gum arabic diſſolved in a quart of boiling water; and after the ink has ſettled, ſtrain it off through a coarſe linen cloth, and keep it well ſtopped for uſe.

Mr. Delaval in his "Treatiſe on Colours," p. 37. informs us, that with an infuſion of galls and iron filings, he had not only made an exceedingly black and durable ink, but by means of it, without the addition of any acid, dyed ſilk and woollen cloth of a good and laſting black. But this kind of ink, though the colour is far ſuperior to that of any other, may be eaſily diſcharged, either by the ſmalleſt quantity of any acid, or even by ſimple water; becauſe it doth not penetrate the paper in ſuch a manner as is neceſſary to preſerve it from the inſtantaneous action of the acid or of the water. During the action of the infuſion of galls upon the iron in making this kind of ink, a very conſiderable effervescence takes place, and a quantity of air is diſcharged, the nature of which has not yet been examined.

Many of the more volatile kinds of oil may be uſed in writing, if reduced to a proper conſiſtence by the addition of gum or reſin. Tolerable ink may be made by diſſolving 30 grains of common reſin in 90 grains of oil of turpentine, and tempering the ſolution with 17½ grains of lamp-black, and 2½ of indigo. In a dry ſtate, this compoſition reſiſts the action of water, but not of ſpirit. Copal is much ſuperior to reſin; it will diſſolve in only few liquids. It may be diſſolved, however, in oil of lavender. The only inconvenience attending the uſe of copal in the compoſition of ink is, that it is ſoluble at a low temperature. Ink may be compoſed of oil of lavender, copal, and lamp-black in the manner following: Take oil of lavender 200 grains, copal, in powder, 25 grains, and lamp-black from 2½ to 3 grains. With the aſſiſtance of a gentle heat, diſſolve the copal in the oil of lavender in a ſmall glaſs phial, and then mix the lamp-black with the ſolution upon a marble ſlab, or other ſmooth ſurface. Put the compoſition into the bottle, and keep it from the air. After the repoſe of ſome hours, the ink muſt be

well ſhaken, and ſtirred with a piece of wire before it is uſed; if it be too thick, it muſt be diluted with a little oil of lavender, oil of turpentine, or alcohol. The facility of writing with this compoſition depends much on the quantity of the colouring matter. Nicholſon's Journal, vol. ii. 8vo.

As the duration of records, and other valuable writings, depends much on the goodneſs of the ink employed, Dr. Lewis has thought this ſubject worthy of his attention. The chief imperfection of common inks is, that they decay in time, and at laſt the writing becomes inviſible. From experiments made by that author, he infers, that the decay of inks is chiefly owing to a deficiency of galls; that the galls are the moſt periſhable ingredient, the quantity of theſe, which gives the greateſt blackneſs at firſt (which is about equal parts with the vitriol) being inſufficient to maintain the colour; that for a durable ink, the quantity of galls cannot be much leſs than three times that of the vitriol; that it cannot be much greater without leſſening the blackneſs of the ink; that by diminiſhing the quantity of water, the ink was rendered blacker and more durable; that diſtilled water, rain water, and hard ſpring-water, had the ſame effects; that white wine produced a deeper black colour than water; that the colour produced by vinegar was deeper than that by wine; that proof ſpirit extracted only a reddiſh-brown tinge, and rectified ſpirit a paler brown; that the laſt mentioned tinctures ſunk into, and ſpread upon the paper; and hence the impropriety of adding ſpirit of wine to ink, as is frequently directed, to prevent mouldineſs or freezing; that other aſtringents, as oak bark, biſtort, ſloe-bark, &c. were not ſo effectual as galls, nor gave ſo good a black, the colour produced by moſt of theſe, excepting oak-bark, being greeniſh; that the juice of ſloes did not produce a black colour with martial vitriol; but that, nevertheleſs, the writing made with it became black, and was found to be more durable than common ink; that inks made with ſaturated ſolutions of iron in nitrous, marine, acetous acids, in tartar, or in lemon juice, were much inferior to the ink made with martial vitriol; that the colour of ink was depraved by adding quicklime, which was done with an intention of deſtroying any ſuperabundant acid which might be ſuppoſed to be the cauſe of the loſs of the colour of the ink; that the beſt method of preventing the effects of this ſuperabundant acid is probably by adding pieces of iron to engage it; and that this conjecture was confirmed by an inſtance the author had heard, of the great durability of the colour of an ink in which pieces of iron had been long immerſed; and laſtly, that a decoction of logwood uſed inſtead of water, ſenſibly improved both the beauty and deepneſs of the black, without diſpoſing it to fade. The ſame author obſerves, that the addition of gum arabic is not only uſeful, by keeping the colouring matter ſuſpended in the fluid, but alſo by preventing the ink from ſpreading, by which means a greater quantity of it is collected on each ſtroke of the pen. Sugar, which is ſometimes added to inks, was found to be much leſs effectual than gums, and to have the inconvenience of preventing the drying of the ink. The colour of ink is found to be greatly injured, by keeping the ink in veſſels made of copper, or of lead, and probably of any other metal excepting iron, which the vitriolic acid can diſſolve. The foregoing experiments point out for the beſt proportions of the ingredients for ink; one part of green vitriol, one part of powdered logwood, and three parts of powdered Aleppo, or blue galls. The beſt menſtruum appears to be vinegar or white wine, though for common uſe water is ſufficient. If the ink be required to be of a full colour, a quart, or at moſt three pints, of liquor may be allowed to three ounces of galls, and to one ounce of each of the other two ingredients. Half an ounce of gum may be added to each pint of the liquor; though the more gum we can employ, conſiſtently with due freedom of writing, it is probable that the ink will be the more durable. The ingredients may be all put together at once in a convenient veſſel, and well ſhaken four or five times each day. In ten or twelve days the ink will be fit for uſe, though it will improve by remaining longer on the ingredients; or it may be made more expeditiouſly, by adding the gum and vitriol to a decoction of galls and logwood in the menſtruum. To the ink, after it has been ſeparated from the feculencies, ſome coarſe powder of galls, from which the fine duſt has been ſifted, together with one or two pieces of iron, may be added, by which its durability will be ſecured.

It has been often remarked, ſays the ſame ingenious writer, that the inks uſed in former times were far more durable than thoſe of later years; many modern records being more decayed than manuſcripts of much greater antiquity, of which we have inſtances in the Letters of Camillo Paderni, publiſhed in the Philoſophical Tranſactions for 1753 and 1754. Dr. Lewis made ſeveral experiments, in order to recover the compoſition of this durable ink. Inſtead of oil which is uſed in the printers' ink, he mixed both lamp-black and ivory-black with a ſolution of gum arabic; this liquor wrote of a fine black colour, but when dry, it rubbed off entirely by moiſture. Concluding, therefore, that the colour could not be ſufficiently fixed on paper without an oily cement, and as oils are made miſcible with watery fluids by the intervention of gum, he mixed ſome of the ſofter printers' varniſh with about half its weight of a thick mucilage of gum arabic, working them well together in a mortar, and beat this maſs with lamp-black, adding water by little and little, and continuing the rubbing, till the mixture became of a due conſiſtence for writing. This produced characters of a full browniſh black colour, which could not be diſcharged by rubbing, nor waſhed out ſo readily as the foregoing. Inſtead of the printers' varniſh, or boiled oil, linſeed-oil was mixed in the ſame manner with mucilage and lamp-black, and the mixture diluted with water; and the ink thus obtained was much the ſame as the other. To prevent the diſcharge by water, ſome of the more ſinking kinds of paper, or common paper made damp as for printing, muſt be uſed, which will admit the ink to ſink a little into its ſubſtance; and thus the characters will be as fixed as can be deſired. Such Dr. Lewis found to be the ancient inks, that were ſo durable. Pliny and Vitruvius expreſsly mention the preparation of ſoot, or lamp-black, and the compoſition of writing ink from lamp-black and gum. Dioſcorides ſets down the proportion of three ounces of the ſoot to one of gum. This mixture was formed into cakes or rolls, and dried in the ſun, which were occaſionally tempered with water, as the Indian ink is with us for painting. The ancients were ſenſible that theſe inks were liable to be diſcharged by water, and endeavoured to obviate this imperfection, according to Pliny, by uſing vinegar, inſtead of water, for tempering the mixture of lamp black and gum, which promotes the ſinking into the paper. After all, none of theſe inks can be diſcharged otherwiſe than by deſign; which is the caſe with reſpect to the vitriolic inks, and thoſe of printed books and copper-plates.

In the courſe of Dr. Lewis's experiments, a farther improvement occurred to him, which was that of uſing the common vitriolic ink, inſtead of water, for tempering the ancient mixture of gum and lamp-black. By this method the writings will have the durability of thoſe of former times, with all the advantage that reſults from the vitriolic ink fixing itſelf in the paper. Common writing ink may, in

many cases, be improved by a small addition of the ancient composition, or of the common Indian ink. Lewis's Commerce of Arts, &c. § 16.

Mr. Astle, in his "Origin of Alphabetical Writing," inculcates the necessity of making ink durable; and for this purpose suggests a comparison of the rolls and records that have been written from the 15th century to the end of the 17th, with the writings that remain from the 5th to the 12th centuries. These are in excellent preservation; but the former, though of more modern date, are defaced to such a degree that they are scarcely visible. Mr. Astle agrees with Dr. Lewis in the opinion, that the ancient inks were composed of soot or ivory black instead of the galls, copperas, and gums, which form the composition of our's. Besides their black ink, the ancients used various other colours, as red, gold and silver, purple, &c. Green ink was frequently used in Latin MSS., especially in the latter ages: and it was frequently employed in signatures by the guardians of the Greek emperors till their wards were of age. Blue or yellow ink was seldom used except in MSS., but, according to Mr. Astle, the yellow has not been much in use for these 600 years. Some kinds of characters, particularly the metallic, were burnished. Wax was used by the Latins and Greeks as a varnish, especially by the former, and particularly in the 9th century. This continued a long time in vogue. Dr. (sir Charles) Blagden, in the Phil. Transf. vol. lxxvii. p. 451, &c. has proposed a new method of recovering the legibility of decayed writings. With this view he made some experiments on parchment and vellum MSS., with which he was furnished by Mr. Astle, employing those chemical re-agents which seemed best adapted to his purpose, *viz.* alkalies, both simple and phlogisticated, the mineral acids, and infusion of galls. The general result shewed, that the ink anciently used, at least in these MSS., was of the same nature as the present; and the greater durability of the more ancient inks appeared to depend very much on a better preparation of the material upon which the writing was made, *viz.* the parchment or vellum. He suspected, however, that the ancient inks contained a rather less proportion of iron than the more modern; and perhaps more gum was used then, or possibly they were washed over with some kind of varnish, though not such as gave any gloss. It occurred to our author, in the course of his experiments, that perhaps one of the best methods of restoring legibility to decayed writings might be to join phlogisticated alkali with the remaining calx of iron. In order to bring this idea to the test, he made several experiments, for which we refer to his paper, ubi supra. The method now commonly practised to restore old writings is the wetting of them with an infusion of galls in white wine. This has certainly a great effect: but, like the phlogisticated alkali, it is apt to stain the substance in which the writing was made. Sir Charles Blagden suggests, that a phlogisticated alkali, better adapted to this purpose than the common, might be prepared, by rendering it as free as possible from iron, diluting it to a certain degree, or substitutng the volatile alkali for the fixed. This would serve to bring out a prodigious body of colour upon letters which were before so pale as to be almost invisible, and it would be preferable to the infusion of galls in this respect, that it produces its effect immediately, and may be confined to those letters only for which such assistance is wanted.

In the "Monthly Review" of the volume of Transactions above cited, the following method is proposed for preventing ink from decaying. It consists in washing over the paper on which the writing is to be made with the colouring matter of Prussian blue; and by writing upon it afterwards with common ink, a ground of Prussian blue is formed under every stroke; which will remain strong after the black has been decayed by the weather, or destroyed by acids. The ink will thus bear a larger proportion of vitriol at first, and will have the advantage of appearing blacker when first written.

Ink *Powder* may be prepared, by infusing a pound of galls powdered, and three ounces of pomegranate-peels, in a gallon of soft water for a week, in a gentle heat; and then straining off the fluid through a coarse linen cloth. Add to it eight ounces of vitriol dissolved in a quart of water, and let them remain for a day or two; preparing in the mean time a decoction of logwood, by boiling a pound of the chips in a gallon of water, till one-third be wasted, and then straining the remaining fluid while it is hot. Mix this decoction and the solution of galls and vitriol together, and add five ounces of gum arabic, and then evaporate the mixture over a common fire to about two quarts; when the remainder must be put into a vessel proper for that purpose, and reduced to dryness in *balneo Mariæ*, i. e. by hanging the vessel in boiling water. The remaining mass, after the fluid is wholly exhaled, must be well powdered; and when it is wanted for use, may be converted into ink by the addition of water.

A portable or extemporaneous ink may be made without galls or vitriol, by mixing half a pound of honey and the yolk of an egg, adding two drams of gum arabic finely levigated, and thickening the whole with lamp-black to the consistence of a stiff paste; which being put to a proper quantity of water, may be used as an ink.

Ink, *Indian*, or *Chinese*, is an admirable composition, in vain attempted to be imitated in Europe. It is not fluid, like our writing inks, but solid, like our mineral colours, though much lighter. They make it of all figures, but the most usual is rectangular, about a quarter of an inch thick. Some of the sticks are gilt with figures of dragons, birds, flowers, &c. In order to do this, they have little wooden moulds, so curiously wrought, that we could hardly equal them in metals.

To use this ink, there must be a little hollow marble, or other stone, with water in it, on which the stick of ink must be ground, till the water becomes of a sufficient blackness. It makes a very black shining ink; and though it be apt to sink when the paper is thin, yet it never runs or spreads; so that the letters are always smooth, and evenly terminated, how big soever they be. It is of great use in designing, because it may be weakened or diminished to any degree; and there is abundance of things which cannot be represented to the life without it.

From an analysis of this ink, Dr Lewis concludes that it contains an animal substance soluble in water, and consists of a black powder, mixed with some animal glue. He tried to imitate it, by mixing some lamp-black, prepared from linseed-oil, by hanging a large copper pan over the flame of a lamp to receive its smoke with as much melted glue as gave it sufficient tenacity for being formed into cakes. These cakes, when dry, answered as well as the genuine Indian ink, in regard both to the colour, and the freedom and smoothness of working. Ivory black, and other charcoal blacks, levigated very fine, had the same effect with the lamp-black. It appears from three receipts for the preparation of Indian ink, in Du Halde's History of China, that the colouring material is lamp-black, to which is added, in one of them, a quantity of horse-chesnuts, burnt till the smoke ceases. The conglutinating matter, in one of the prescriptions, is a thin size of neat's leather; in another, a solution of gum tragacanth, and in the other, a mixture of size, with a de-

coction of certain vegetables, unknown to us. Du Halde observes, that the Chinese have inks of different goodness and price; that the most essential difference proceeds from the quality of the lamp-black, and that the best is the soot of oil, burnt in lamps, in apartments fitted up for this purpose.

The Chinese have often attempted to use this in their porcelain, to give the colour of black to the figure traced on white vessels, but it has been a vain attempt; for however beautiful and strong the figures might appear when first laid on, and even when the vessels were dried, it all disappeared on the baking, and they came out quite white as they were put in. The colours for this use must be such as can penetrate the varnish, and endure the fire. Mineral colours are found to have these qualities, and these alone therefore are to be employed; such light ones as this black burning off from the surface, and wholly disappearing. Obs. sur les Coûtumes de l' Asie, p. 329.

Ink is also an appellation given to any coloured liquor used in the same manner as black ink; as red, green, blue, yellow, &c. inks. *Red* writing ink is prepared by infusing a quarter of a pound of the raspings of Brazil wood for two or three days in vinegar; boiling the infusion for an hour over a gentle fire, and afterwards filtering it, while hot, through paper laid in an earthen cullender; then put it again over the fire, and dissolve in it, first, half an ounce of gum arabic, and afterwards alum, and white sugar, of each half an ounce. Red ink may be also made of vermilion, by beating together the glair of four eggs, a tea-spoonful of white sugar, or sugar-candy, powdered, and as much spirit of wine, till they be of the consistence of oil; then adding such a proportion of vermilion as will produce a red colour of sufficient strength; the mixture should be kept in a small phial, or well-stopt ink bottle, and well shook before it be used. Gum-water is often used instead of the glair of eggs; but thin size made of isinglass, with a little honey, is much better for the purpose. Red ink may be made by tempering the solution of copal with red sulphuret of mercury, *e.g.* take of oil of lavender, 120 grains, copal, in powder, 17 grains, and red sulphuret of mercury, 60 grains, dissolve the copal in the oil, and then mix the sulphuret with the solution upon a smooth surface. This, and also the black ink made with copal, possess a permanent colour, and other essential properties of the ink used in printing. The oil of lavender being dissipated with a gentle heat, the colour is left on the paper surrounded with copal, a substance insoluble in water, in spirits, in acids, or in alkaline solutions.

For red printing ink, see Printing.

Green ink may be made, by putting an ounce of powdered verdigris to a quart of vinegar, and straining the fluid, after it has stood two or three days: or, instead of this, the crystals of verdigris dissolved in water will answer the purpose; then dissolve in a pint of either of these solutions, five drams of gum arabic, and two drams of white sugar.

Blue ink is made by grinding indigo with honey and the white of eggs, and making it fluid with water.

Yellow ink is made by an infusion of saffron in water, with a little alum and gum arabic: or, by boiling two ounces of Avignon, or French berries, in a quart of water, with half an ounce of alum, till one-third of the fluid be evaporated, and then dissolving in it two drams of gum arabic, and one dram of sugar, and afterwards a dram of powdered alum.

In general, inks of all colours may be made by using a strong decoction of the ingredients used for dyeing, mixed with a little alum and gum arabic. See the several colour Blue, Green, &c.

Inks, *Sympathetic*, or *Secret*. Every sort of liquor with which a person may write, so that the letters do not appear till there is some particular means used to give them a colour different from that of the paper, is called by the name of *sympathetic* ink; and of this there are a great many kinds described in the writings of Baptista Porta, Lemery, and other authors.

All these inks may be regularly distributed into different classes, according to the different means which are to be used to make them appear; and these are in general the four following. 1. By giving a new liquor, or the vapour of new liquor, a place on the paper, on which the letters are written with the natural invisible ink. 2. By exposing the paper to the air, by which means the letters at first invisible will appear. 3. By passing gently over the letters a matter of some remarkable colour reduced to fine powder. And 4. By exposing the paper to the fire.

This last is by much the best method, and is so general, that it may be prudently used to all papers suspected of containing any secret writing, as it seldom fails to discover it. All the common inks of this kind, however, when they have been once made to appear, either by fire or by any other method, can never be made to disappear again; but there is one kind described by Mr. Hellot, in the Memoirs of the Academy of Sciences at Paris, and since tried many times with us, and elsewhere, which, though the letters it gives are in themselves invisible, and appear like those of some other of these inks, on their being held to the fire, yet they after that will fade and disappear on the paper again, and may be reproduced in this manner several times. This, therefore, is the first known ink of a fifth general class, of which future researches may discover perhaps more.

Of the first class of sympathetic inks, or those which do not appear till the paper on which they are written be made to imbibe another liquor, or the vapour of another liquor, are the following kinds.

To two or three parts of unslaked lime put one of yellow orpiment; powder and mix the two, adding fifteen or sixteen times as much water as there was orpiment; stop up the phial with a cork and bladder, and set it in warm embers; shake the phial now and then for five hours, and warily decant the clear part, or rather filtrate it. In the room of this preparation may be used a saturated solution of common brimstone, made by boiling the brimstone either with quick-lime, or in strong alkaline ley. In the mean time, burn a piece of cork thoroughly, and when well inflamed, quench it in common water, or rather in brandy. Being thus reduced into a friable coal, grind it with fair water, wherein gum arabic has been dissolved; and it will make a liquor as black as the common ink.

While these are doing, dissolve, in three times as much distilled or strong vinegar, over warm embers, a quantity of red lead, or of saccharum saturni, in thrice the quantity of water, for three or four hours, or till the liquor have a sweet taste. This liquor will be as clear as common water. Solutions of lead in aquafortis answer the same end, except that, when written with, they are apt to corrode the paper.

The liquors thus prepared, write any thing on paper with this last sort, dry it, and nothing will appear. Over the place, write what you please with the second liquor: it will appear as if written with common ink: when dry, dip a small piece of rag or spunge, in the first liquor, rub it over the written place, and the black writing will vanish; and that wrote with the invisible ink will appear black and legible.

Again, take a book four or five inches thick, and on the first leaf write any thing with the last liquor; turn to the other end of the book, and rub there with a rag, dipt in the first liquor, on that part, as near as you can guess, opposite to the writing, and leave also the rag there, clapping a paper over it; then nimbly shutting the book, strike four or five smart strokes thereon with your hand, and turning the other side uppermost, clap it into a press, or lay it under a good weight for a quarter of an hour, or even half that time; then will the writing done with the invisible ink be found legible there.

The above operation may be varied, by writing the invisible characters with the solution of bismuth in nitrous acid, and exposing them to the vapours of liver of sulphur, or moistening them with a solution of liver of sulphur.

Dissolve white or green vitriol in water, and writing with the solution, nothing will appear. Boil galls in water, and dip a linen rag in the decoction, and with it rub the place before writ, and it will appear black and legible. Rub it over again with spirit of vitriol, or its oil, and the writing will disappear again; rub it over again with oil of tartar per deliquium, the letters will appear again, but of a yellow colour. If the blackness of ordinary ink be destroyed by a sufficient quantity of nitrous acid, the writing made by it will remain invisible till it be moistened with liquid fixed alkali.

The golden sympathetic ink.—This is made by dissolving in aqua regia as much gold as that menstruum can take up, and then adding to the liquor five or six times as much water; in another vessel there must be some tin dissolved in aqua regia; and when that menstruum has also taken up as much of the metal as it can, there is to be added to it an equal quantity of common water. The letters must be written on white paper with the solution of gold, and the writing being dried in the shade, the letters will not appear, at least not for seven or eight hours afterwards; dip a pencil in the solution of tin, and rub that over the solution of gold with which the letters were written, and they will appear of a beautiful purple. It might be supposed, that any other metals which were soluble in the same acid menstruum would equally produce this effect; but experiment shews, that this is not the case; and silver and copper, though both soluble in aquafortis, yet produce no change of colour by these precipitations made by mixing the solutions of them on paper; and this example of such an effect in the solutions of gold and tin, is an exception to the general rules in the solutions of metals, and their effects on one another.

The purple colour of these letters may be again effaced by rubbing some simple aqua regia over the paper, and may be made to appear again by rubbing over that the solution of tin. Kunkel, Cassius and Orschal, with some other writers, made the first steps towards this discovery, by their attempt to give crystal, by means of gold, the colour of the oriental rubies. There are, beside these mineral preparations, some vegetable ones, which give the same phenomena, but these are the more certain.

Of the second kind of sympathetic inks, or those which appear on being exposed only to the air, is the golden ink made by adding to a solution of gold in aqua regia, so much water that the liquor shall not stain a white paper: letters written with this will not appear till the paper has been exposed some hours to the open air, and they will then begin to acquire a colour by degrees, till they at length become of a deep violet colour, tending to black. If, instead of exposing the paper to the air, it be kept in a box close shut up, or closely folded in other paper, it will remain invisible two or three months; but at the end of that time it will begin to appear, and will by degrees become of a deep violet colour. So long as the gold remains united to its dissolvent, it is yellow; but the acid that dissolves it being of a volatile nature, the greater part of it evaporates, and leaves no more than is just necessary to colour the calx of gold which remains upon the paper.

The second of these is the silver ink, made by a solution of silver in aquafortis, weakened by distilled water, till it will not stain the paper. Letters written with this will be invisible for three or four months, if shut up in a box; but if they be exposed to the sun they become legible in about an hour, because by this means the evaporation of the acid is accelerated. The letters written with this ink are of a slate colour; and that from the sulphureous nature of the aquafortis, every thing that is sulphureous blackening silver. This blackish colour, however, is not permanent; for the sulphureous part finally evaporating, the letters are left to their natural appearance, and are of a fine true silver colour, if the silver that was used was fine, and the place open.

In this class there may also be placed several metallic dissolutions; as that of lead in vinegar, and of copper in aquafortis, which give at length a brownish colour upon the paper; as also the solution of tin in aqua regia, of mercury in aquafortis, of iron in vinegar, of emery and several of the pyritæ in spirit of salt. But all these, though they give letters which are after some time legible, on being exposed to the air, are also made to appear instantly on the paper, holding them to the fire. Each of these solutions gives its own particular colour; but they have all thus disadvantage, that in time they eat away the paper, and the letters are seen in the shape of so many holes.

Of the third class of ink, or that which appears on rubbing over the paper with a brown or black powder, are almost all the glutinous expressed juices of plants, which are themselves of no remarkable colour, the milk of animals, or any other thick and viscous fluids. To use these, the letters must be written on a white paper, and when dry, there is to be thrown over them the fine powder of any coloured earth, or other such substance; and the writing will afterwards appear coloured, because its viscous quality remains sufficiently in it for the entangling and retaining this fine powder, though it falls easily off from every other part of the paper. Mem. Acad. Science, Par. 1737.

Among the methods which Ovid teaches young women to deceive their guardians, when they write to their lovers, he mentions that of writing with new milk, and of making the writing legible by coal-dust, or soot.

> "Tuta quoque est, fallitque oculos, e lacte recenti
> Litera: carbonis pulvere tange: leges."
>
> De Arte Amandi, l. iii. v. 629.

Ausonius proposes the same means to Paulinus, and he afterwards teaches other methods of secret writing. Auson. Epist. xxiii. v. 21, &c. Eneas, in Poliorceticis, cap. 31, and Gellius, lib. xvii. cap. 9, mention the like. Pliny, lib. xxvi. cap. 8. mentions the milky sap of certain plants for a similar purpose.

Of the fourth class, or those inks which become visible on holding them to the fire, there are a vast number; and indeed all infusions, the matter of which is readily burnt to a sort of charcoal by a little fire, will answer this purpose. The nicest of this kind is the sal ammoniac ink, made by dissolving a scruple of sal ammoniac in two ounces of fair water. Letters written with this solution are invisible on the paper, till it is held before the fire, or has an

iron a little heated paſſed over it. The rationale of this is, that the inflammable part of the ſal ammoniac is burnt to charcoal by a heat which is not ſufficient to ſcorch the paper; and this is the caſe with all the reſt of this claſs. The letters written with this ſolution are, however, of no great duration; for the ſalt being apt to moiſten in the air, the letters ſoon ſpread, and run together in a confuſed manner.

Dr. Lewis ſays, that all the ſalts which he has tried produce this effect in a greater or leſs degree; nitre, alum, tartar, very weakly; ſea-ſalt more ſtrongly; fixed alkaline ſalts ſtill more ſo; but ſal ammoniac the ſtrongeſt of all. Metallic ſolutions, made in acids, and diluted ſo as not to corrode the paper, act in the ſame manner. The juice of lemons and milk have alſo been uſed as ſympathetic inks, the writing with which appears upon the application of heat ſufficient to decompoſe the oily and mucilaginous parts of theſe liquors.

The fifth claſs of ſympathetic ink contains only one yet known kind.

This, though in itſelf inviſible, becomes of a blueiſh green when held to the fire; and this colour diſappears again as the paper cools, and is to be produced again on holding it again to the fire: and this for a long time, and a repeated ſeries of trials. It may alſo, according to the different manner of treating it, be made to appear blue, green, yellow, red, and ſome other colours. This property of the tinging matter of biſmuth ore was publiſhed at full length by a German lady, in 1705.

A certain German chemiſt ſhewed the academy at Paris a ſalt of roſe-water, which became blue on holding it to the fire, and at the ſame time ſhewed the ore from which he procured the ſalt, which he called an ore of marcaſite, a name given by many to the biſmuth ore. He added, that this was the mineral from which the fine blue ſmalt of Sneeberg was prepared, and that no other ore but this afforded it, and that he made the tincture from this mineral with aquafortis, which he fixed with ſea-ſalt.

This was the ſubſtance of what the German declared, and from what Mr. Hellot, in 1736, took the hint for his diſcovery of this remarkable ink. The ſalt was, after many experiments, at length found to be produced from an arſenic ore; and it was found, that all the cobalts and ores of biſmuth afford a tincture capable of theſe changes by fire.

The method of preparing it is this: pour upon two ounces of arſenic ore, groſsly powdered, a mixture of five ounces of aquafortis, and five ounces of common water. After the firſt ebullition is over, place the veſſel in a gentle ſand-heat, and let it ſtand there till no more air-bubbles ſeem to aſcend; after this increaſe the fire, ſo as to make the liquor boil for about a quarter of an hour; after this the liquor will become of a reddiſh colour, and when cold it is to be decanted clear off from this ſediment into a phial; and after ſtanding in that ſome time, it is to be again decanted off from what is precipitated there; and ſo on for three or four times till it is quite clear; for it muſt not be filtered, leſt the acid ſhould take ſomething from the paper that might ſpoil the effects. When the liquor is clear, there muſt be added to it two ounces of white ſea-ſalt: this mixture is to be evaporated over a gentle ſand-heat, till there remains only a dry ſaline maſs. When the liquor is grown hot, it changes from its orange colour to a fair red; and when the aqueous humidity is evaporated, it becomes of a beautiful emerald colour, and from this, as it dries up, it changes by degrees to a dirty green, like that of verdigris in the cake. As it becomes nearly dry, it muſt be ſtirred about with a glaſs rod or peſtle, to keep it from uniting into a maſs; and it muſt not be kept over the fire till perfectly dry, becauſe by that means the colour is often loſt, and the ſalt from green becomes of a duſky yellow; but if it be taken from the fire while it is green, it gradually becomes reddiſh as it cools, and finally is of a roſe-colour. The manner of uſing this ſympathetic ink is this: write with it on a fine and ſmooth paper, or draw with a black-lead pencil the figure of a plant or tree on the paper; then trace over the ſame lines with this liquor; let it dry in the open air, and then rub off the black lines with bread, and the paper will appear altogether fair, though the lines made by the ink are in reality ſunk deep into it. On holding this paper to the fire the lines will all appear, and the figure of the plant or the letters will be painted in a beautiful blueiſh green, which will continue ſo long as the paper is warm; but when it is cold again, they will wholly diſappear. The lines, therefore, diſappear much ſooner in winter than in ſummer; and in very hot weather it is often neceſſary to lay the paper on a marble, or other very cold body, in order to produce this effect. At any time, if the paper be ſcorched in the experiment, the colour of the lines will not diſappear again, even if ice be laid upon them. If the writing be expoſed for three or four days to a humid air, the lines will appear of a fine pale red. If the impregnation of the ore of biſmuth, inſtead of ſea-ſalt, have alum added to it, and the whole proceſs be continued as before deſcribed; and if letters be written with the red liquor as it is taken out of the veſſel, the letters will not appear even on holding it to the fire; but if the paper be wetted over with a clear ſolution of marine ſalt, and then left to dry, and afterwards held to the fire, the letters will appear blue. The ſame alſo will be the effect, if the writing be expoſed to the vapour of hot ſpirit of ſalt. When this preparation is thus made with alum, inſtead of common ſalt, the liquor never becomes green, but continues red, and never changes colour in the drying, or afterwards. The green colour ſeems to be wholly the effect of the ſea-ſalt; for not only this aluminate impregnation, but others in which other ſalts had been employed, were always found to be of a different colour.

Glauber's ſalt, uſed inſtead of common ſea-ſalt, left the maſs red in the ſame manner as alum did. Nitre added, inſtead of ſea-ſalt, gave the precipitate or dried ſalt a beautiful purple colour, which became white on the inſtant that water was poured upon it, and a roſe-coloured tincture was drawn from it, which gave lines or letters on paper, which continued inviſible as long as they were cold, but aſſumed a beautiful red on holding the paper to the fire; which colour they retained no longer than while the paper continued warm, diſappearing afterwards in the ſame manner with the green colours made by the ſea-ſalt; and if a ſimple ſolution of ſea-ſalt be rubbed over the paper, and ſuffered to dry, and the paper be afterwards heated, the lines appear blue. Borax has the ſame effect in this preparation with the nitre. All theſe experiments were made with the neutral ſalts; but in order to try what would be the effects of alkalies in the mixture, Mr. Hellot added to three ounces of the impregnation of the ore in aquafortis, pure ſalt of tartar, till the ebullition ceaſed; but the conſequence of this was no great precipitation, but merely the ſubſiding of a ſmall white ſediment; this mixture being evaporated nearly to a dryneſs, the remaining maſs, ſo long as it was warm, appeared of a beautiful purple; but this became paler as it dried, and turned white in an inſtant on pour-

ing water upon it. This diffolved in water, in the manner of the others, gave lines on paper of a faint rofe-colour, which appeared or difappeared in the manner of thofe made by the other folutions, according as the paper was hot or cold; and the wetting of the paper with a folution of fea-falt, had the fame effects on this as on the others, making the lines appear blue on holding to the fire. Mem. Acad. Par. 1737. See *Colours from* METALS.

The ink may be eafily made by digefting zaffre, commonly fold by druggifts, in aqua regia; and thus is obtained the foluble part of zaffre, which is the calx of cobalt. This folution is then to be diluted with a little common water. In expofing the paper written with this folution to the fire, care muft be taken not to heat it too much; for in this cafe, the writing will not again difappear by expofure to cold. This ink, fays Macquer, the author of the Chemical Dictionary, may be applied to the drawing of landfcapes, in which the earth and trees deftitute of verdure, being drawn with common ink, give a profpect of winter; and which may be made to affume the appearance of fpring, by expofure to a gentle heat, which covers the trees with leaves and the earth with grafs, by rendering vifible thofe parts of the landfcapes which are drawn with this fympathetic ink; and, as the folution of regulus of cobalt or zaffre in fpirit of nitre acquires a reddifh colour by the application of heat, the red folution might be contrived to reprefent the fruits and flowers.

Joinery

JOINERY is a branch in *Civil Architecture*, and confifts of the art of framing or joining wood together, for internal and external finifhings of houfes; as the coverings and linings of rough walls, or the coverings of rough timbers, and of the conftruction of doors, windows, and ftairs.

Hence joinery requires much more accurate and nice workmanfhip than carpentry, which confifts only of rough timbers, ufed in fupporting the various parts of an edifice: joinery is therefore ufed by way of decoration only, and being always near to the eye, and confequently liable to infpection, requires that the joints fhould be fitted together with the utmoft care, and the furfaces made fmooth.

The wood ufed is called ftuff, and is previoufly formed by the pit-faw into rectangular prifms, which are denominated boards, battens, or planks, according to their breadth. Battens run from two to feven inches wide, boards from feven to nine inches wide, and planks from nine inches to any greater breadth that can be cut out of a piece of wood.

The operations of joinery confift of forming furfaces of various kinds, alfo of grooving, rebating, and moulding, and of mortifing and tenoning, and laftly, of joining two or feveral pieces together, fo as to form a frame or folid mafs.

Surfaces, in joinery, are either plane or curved, but moft frequently plane.

All kinds of furfaces are firft formed in the rough, and finally brought to exact forms by means of tools adapted thereto.

Grooving confifts in taking away a part of a rectangular fection from a piece of wood, fo as to form a channel of equal breadth throughout, with three furfaces, one being parallel, and the other two perpendicular to the furface of the wood from which the channel is receffed: the channel thus formed is called a groove.

Rebating confifts in taking away a part from a piece of wood of a rectangular fection, fo as to leave only two fides, each of a parallel breadth, the one fide being perpendicular to the furface of the wood, and the other parallel thereto: the cavity thus formed is called a rebate. From this definition it is manifeft, that a rebate can only be formed by reducing the piece of wood to be rebated at the angle itfelf, and may therefore be looked upon as a half groove.

A mortife is a cavity receffed within the furface of a piece of wood, with four fides perpendicular to that furface, and likewife to each other: the act of making a mortife is called mortifing.

A tenon is a projection formed on the end of a piece of wood with four plane fides, at right angles to each other, and to a plane, from which it projects; and this plane is called the fhoulder of the tenon.

In the following, all pieces of wood whatever are fuppofed to be rectangular prifms, and the length in a direction of the fibres; two of the fides of every mortife to be perpendicular, and the other two fides parallel to the fibres; the four fides of every tenon in the direction of the fibres, unlefs otherwife afferted: likewife, if two of the furfaces of a piece of wood be of greater breadth than the other two, thefe are called the edges and thofe the fides, and each line of concourfe, formed by two adjacent fides, is called an arris.

Moulding confifts in forming the furface of a piece by curve or plane furfaces, or by both, in fuch a manner, that

all parallel fections will be fimilar figures, that is, their boundaries may be made all to coincide.

The firft thing to be done in joinery is to felect the ftuff or boards, which ought to be well feafoned for every purpofe in joinery, and then line it out; and if the ftuff is not already at the fize, as is moft frequently the cafe, it muft be ripped out with the ripping faw, or crofs cut with the hand faw, or both, as may be wanted. The next thing is the planing of the ftuff firft upon a fide, then the edge fquared, and then gaged to a breadth and thicknefs, fhould either or both be found neceffary.

Two or more pieces of ftuff may be faftened together in various ways by pins of wood or by nails, but in work prepared by the joiner for the ufe of building, pieces are more frequently joined together by making their furfaces coincide, and then plaftering them over with a hot tenacious liquid called glue, then rubbing the furfaces until the glue has been almoft rubbed out, and the one piece brought to its fituation with refpect to the other. The beft work is always joined by this method.

When boards are required of a greater breadth than common, feveral common boards muft be faftened together edge to edge, either by nailing them to pieces extending acrofs the breadth, or gluing them edge to edge, or by joining pieces tranfverfely together with fmall boards, tongued and grooved into the interftices.

Two pieces of ftuff are joined together at right or oblique angles by mortife and tenon adapted to each other, and faftened together with glue. When a frame, confifting of feveral pieces, is required, the mortifes and tenons are fitted together, and the joints glued all at one time, then entered to their places, and forced together by means of an inftrument called a cramp.

The operation of forming a given furface, by taking away the fuperfluous wood, is called planing, and the tools themfelves planes.

The firft tools ufed by joiners are bench planes, which generally confift of a jack plane, for taking away the rough of the faw and the fuperfluous wood, only leaving fo much as is fufficient to fmooth the furface; the trying plane to fmooth or reduce the ridges left by the jack plane, and to ftraighten or regulate the furface, whether it be plane or convex; the long plane when the furface is required to be very ftraight; and the fmoothing plane in fmoothing, as its name implies, and giving the laft finifh to the work.

Befides the bench planes there are others for forming any kind of prifmatic furfaces whatever, as rebating planes, grooving planes, and moulding planes: but for a more particular defcription of thefe and the bench planes, we fhall refer to the article PLANE.

The tools employed in boring cylindric holes are a ftock with bits of various defcriptions and fizes, gimblets and brad awls of feveral diameters.

The tools ufed in paring the wood obliquely, or acrofs the fibres, and for cutting rectangular prifmatic cavities, are in general denominated chiffels: thofe for paring the wood acrofs the fibres are called firmers, or paring chiffels, and thofe for cutting rectangular prifmatic cavities, are called mortife chiffels, the rectangular cavities themfelves being called mortifes when made to receive a projection of the fame form and fize, and by this means to faften two pieces of wood together at any angle. The fides of all chiffels, in a direction of their length, are ftraight, and the fide of a chiffel which contains the cutting edge at the end is fteel. The beft paring chiffels are made entirely of caft fteel. Chiffels for paring concave furfaces are denominated gouges.

Dividing wood, by cutting away a very thin portion of the material of equal thicknefs throughout, to any required extent, by means of a thin plate of fteel with a toothed edge, is called fawing, and the inftruments themfelves are called faws, which are of feveral kinds, as the ripping faw, for dividing boards into feparate pieces in a direction of the fibres; the hand faw, for crofs cutting and fawing thin pieces in a direction of the grain; the pannel faw, either for crofs cutting or cutting very thin boards longitudinally; the tenon faw, with a thick iron back, for making an incifion of any depth below the furface of the wood, and for cutting pieces entirely through, not exceeding the breadth of that part of the plate without the iron back; likewife a fafh faw and a dovetail faw, ufed much in the fame way as the tenon faw. From the thinnefs of the plates of thefe three laft faws, it is neceffary to ftiffen them by a ftrong piece of metal called the back, which is grooved to receive the upper edge of the plate that is fixed to the back, and which is thereby fecured and prevented from buckling. When it is required to divide boards into curved pieces, a very narrow faw without a back, called a compafs faw, is ufed, and in cutting a very fmall hole a faw of a fimilar defcription, called a key-hole faw, is employed. All thefe faws have their plates longer and thinner, and their teeth finer, as they fucceed each other in the order here mentioned, excepting the two laft, which have thicker plates and coarfer teeth than either the fafh or dovetail faw. The external and internal angles of the teeth of all faws are generally formed at an angle of 60 degrees, and the front edge teeth flope backward in a fmall degree, but incline or recline from the ftraight line drawn from the interior angle perpendicular to the edge in the plane of the plate, as the faw may be employed in ripping or in crofs cutting, or cutting perpendicular to the fibres. The teeth of all faws, except turning and key-hole faws, are bent on contrary fides of the plate, each two teeth fucceeding each other, being alike bent on the different fides of the plate; *viz.* the one as much to the one fide as the other is to the other fide, and confequently all the teeth on the fame fide alike bent throughout the length of the plate for the purpofe of clearing the fides of the cut which it makes in the wood.

Of all cutting tools whatever, the faw is the moft ufeful to the joiner, as the timber or wood which he employs can be divided into flips or bars of any fize, with no more wafte of ftuff than a flice, the breadth of which is equal to the depth of the piece to be cut through, and the thicknefs equal to the diftance of the teeth between their extreme points on the alternate fides of the faw meafured on a line perpendicular to the faid fides: whereas, without the ufe of the faw, cylindrical trees could only be reduced to the intended fize by means of the axe; in the ufe of which there would not only be an immenfe confumption of ftuff, but alfo much greater labour would be required to ftraighten it.

Joiners ufe a fmall axe, called a hatchet, for cutting off the fuperfluous wood from the edge of a piece of a board, when the wafte is not of fufficient confequence to be fawn.

All the above are what are commonly denominated edge tools, but there are others required to regulate the forms. All angles whatever are formed by other reverfed angles of the fame number of degrees as an exterior angle by an interior one, and the contrary. The inftrument for trying right angles is called a fquare, and thofe for trying oblique angles are called bevels. The two fides which form the edge of a fquare are always ftationary, but thofe of bevels are generally moveable one leg upon the other round a joint.

In fome cafes, where a great number of pieces are required to be wrought to the fame angle, a ftationary bevel, called a joint hook, is ufed.

When it is required to reduce a piece of ftuff to a parallel breadth, an inftrument called a gage is ufed for the purpofe. The gage confifts generally of a fquare piece with a fquare mortife, through which a bar at right angles thereto is fitted and made to flide. The bar, which is called the ftem, has a fharp point, cutter, or tooth at one extremity, projecting a little from the furface, fo that when the fide of the gage, next to the end which has the point, is applied upon the vertical furface of the wood, with the flat fide of the ftem which has the tooth upon the horizontal furface, and pufhed and drawn alternately by the workman from and towards him, the cutter will make an incifion from the furface into the wood, at a parallel diftance from the upper edge of the vertical fide on the right hand. This line, fo drawn, will mark out with precifion, and fhew the fuperfluous ftuff to be taken away.

When a mortife is required to be cut in a piece of wood, a gage with two teeth is ufed. The conftruction of this inftrument is the fame as the common gage; but in addition thereto, the ftem has a longitudinal flider with a tooth projecting from the end of the flider, fo that the two teeth may be brought nearer, or to any remote diftance from each other, at pleafure; and alfo to any diftance, from the face of the head or guide within the reach of the ftem.

When wood has been planed, and required to be fawn acrofs the fibres, and as it is neceffary to be kept ftationary while fawing, in order to prevent the fides or the edges from being bruifed, joiners ufe a flat piece of wood with two projecting knobs on the oppofite fides, one at each end, called a fide hook. The vertical fide of the interior angle of one of the knobs is placed clofe to the vertical fide, and the under fide upon the top of the bench; then the wood is preffed againft the knob which projects from the upper furface while it is cutting with the faw: but the ufe of two fide hooks is better, as they keep the piece of wood to be fawn more fteady.

When it is required to cut a piece of wood to a mitre with one fide; that is, to half a right angle, joiners ufe a trunk of wood with three fides, like a box without ends, or a top, the fides and bottom being parallel pieces, and the fides of equal heights: through each of the oppofite fides is cut a kerf in a plane, perpendicular to the bottom, at oblique angles of 45 and 135 degrees, with the planes of the fides; and another kerf is made in the fame manner, fo as to have its plane at right angles to the former. The trunk thus conftructed is called a mitre-box. When the wood is to be cut, the mitre-box is fixed fteady againft two fide hooks, and the piece, which is always lefs than the interior breadth of the mitre-box, is laid within, and preffed againft the farther interior angle of the mitre-box with the fide downwards, to which the faw-kerf is intended to be perpendicular, and in this pofition it is to be cut. The two kerfs in the fides of the mitre-box are requifite, in order to form the acute angle on the right or left-hand fide of the piece, as may be required.

When it is required to make a piece of wood ftraight in one direction, joiners ufe a flip of wood ftraightened on one edge, from which the flip of wood itfelf is called a ftraight edge. Its ufe is obvious; by its application it will be feen whether there is a coincidence between the ftraight edge and the furface.

When it is required to know whether the furface of a piece of wood is in the fame plane, joiners ufe two flips of wood ftraightened each on one edge with the oppofite edge parallel, and both pieces of the fame breadth between the parallel edges: each piece has therefore two ftraight edges. Suppofe it were required to know whether a board is twifted or its furface in a plane, the workman lays one of the flips acrofs the one end, and the other acrofs the other end of the board, with one of the ftraight edges of each upon the furface; then he looks in the longitudinal direction of the board, over the upper edges of the two flips, until his eye and the two upper edges of the flips are in one plane; or otherwife, the interfection of the plane, paffing through the eye and the upper edge of the neareft flip, interfect the upper edge of the farther flip. If it happen as in the former cafe, the ends of the wood under the flips are in the fame plane; but fhould it happen as in the latter, they are not. In this laft cafe the furface is faid to wind; and when the furface is fo reduced that every two lines are in one plane, it is faid to be out of winding, which implies its being an entire plane: from the ufe of thefe flips they are denominated winding fticks.

Before we can proceed to the method of bringing a rough furface to a plane, it will firft be neceffary to fhew how to make a ftraight edge or ruller.

Here the joiner muft not lofe fight of the definition of a ftraight line, *viz.* a ftraight line is that which will always coincide with another ftraight line, however applied together.

The operation of making the edge of a board ftraight is called by joiners fhooting, and the edge fo made is faid to be fhot.

Straight edges may be thus formed; plane the edges of two boards and apply them together, fo that the fuperficies or faces of the boards be in the fame plane, and if there be no cavity between the joint the edges will be ftraight; but if not, the faces muft be applied to each other, the edges brought together, and planed and tried as before, until they are found to coincide.

Another mode is by having a plane furface given: plane the edges of a board as ftraight as the eye will admit of, and apply the face of it to that of the plane, and by the edge of the board draw a line, turn the board over with the other fide upon the plane, and bring the planed edge to the line drawn before, and the extremities of the edges to their former places, and draw another line; then if all the parts of this line coincide with the former line, the edge is already ftraight, but if not, repeat the operation as often as may be found neceffary.

Another mode is to plane the edge of a board as ftraight as the eye will admit of; then plane the edge of another board until it is made to coincide with the former; take a third board and plane the edge of this in like manner, by making it coincide with the edge of the firft board; apply the edges of the two laft boards together, then if they coincide the operation is at an end, but if not, repeat it as often as may be found neceffary.

By any of the methods now fhewn, the fuperficies of the boards, to be fhot, are fuppofed to be parallel planes not very diftant from each other; for if the faces be not parallel, or if the thicknefs be confiderable, the operation will be the more liable to error.

To reduce the rough furface of a body to a plane.—This will not be very difficult, when it is known that a plane is that which will every where coincide with a ftraight line.

The moft practical methods are the following: Let the workman provide two winding fticks, and apply them as before directed, making the ends out of winding if they are not found to be fo; then if all the parts of the furface are ftraight on which the edges of the winding fticks were

placed, it is evident that the whole furface muft be plane. If the furface is hollow between the faid lines, one of the ends or both muft be planed lower, until the furface acquires a fmall convexity in the length, and then, if ftraightened between the ftraight lines at the ends, it will be a perfect plane.

Another mode of forming a plane of the furface is of a quadrilateral form: apply a ruler along the diagonals, then if they are ftraight they are in a plane, but if they are both hollow, or both round, the furface to be reduced is either concave or convex, and muft be ftraightened in thefe directions accordingly; and, laftly, if by trying acrofs the diagonals with the ftraight edge it be found that the one be hollow and the other round, the furface of the board winds. In this cafe bring down the protuberant part of the convex diagonal, fo as to be ftraight with the two extremities; then ftraighten the concave diagonal, by planing either of the two ends or both of them, according as the thicknefs of the board will require. Both diagonals being now ftraight, traverfe the wood, that is, plane it acrofs the fibres, until all the protuberant parts between the diagonals are removed; then the workman may proceed to fmooth it by working it in the direction of the fibres.

To join any number of planks together, fo as to form a board of a determinate breadth, the fibres of each running longitudinal to thofe of any other.—Shoot the two edges that are to be joined; turn the fides of the boards towards each other, fo that the edges that are fhot may be both uppermoft; fpread thefe edges over with ftrong glue of a proper confiftence, made very hot; one of the boards being fixed, turn the other upon it, fo that the two edges may coincide, and that the faces may be both in the fame plane; rub the upper one to and fro in the direction of the fibres till the glue is almoft out of the joint; let thefe dry for a few hours; then proceed to make another joint; continue to join as many boards or planks in the fame manner, till the whole intended breadth be made out. If the boards or planks of which the board is to be compofed are very long, the edges that are to be united would require to be warmed before a fire; and, for rubbing and keeping the joints fair to each other, three men would be found neceffary, one at each extremity, and one at the middle. Boards, glued together with this kind of cement, will ftand as long as the fubftance of the deals or planks compofing them, if not expofed to rain or intenfe heat, provided that the wood has been well feafoned beforehand, and that the grain be free and ftraight, uninterrupted with few or no knots. When a board which is to be expofed to the weather is to be made of feveral boards or planks, the cement to be ufed for uniting them fhould not be of fkin glue, but of white lead ground up with linfeed-oil, fo thin that the colour may be fenfibly changed into a whitifh caft: this kind of glue will require a much greater time to dry than fkin glue. Boards to be expofed to the weather, when their thicknefs will admit, are frequently tongued together; that is, the edges of both boards are grooved to an equal diftance from the faces, and to an equal depth; and a flip of wood is made to fit the cavity made in both: this flip fhould be made to fill the grooves, but ought not to be fo tight as to prevent the joint from being rubbed with proper cement.

To glue any two boards together forming a given angle.—This may either be accomplifhed by fhooting the edge of the one board to the whole of the given angle, and the face of the other ftraight; then, by applying thefe two furfaces together, and rubbing as before, they will form the angle required; or, if the two edges are fhot to half the given angle, and the edges applied together and rubbed and fet as before, the faces of the boards will form the angle required. In both thefe methods, when only one fide of the board is to be expofed to fight, which is moft commonly the cafe, pieces of wood called blocks are fitted to the angle, and the fides glued acrofs the joint or legs of the angle, being previoufly planed for that purpofe.

To form wooden architraves for apertures by gluing longitudinal pieces together.—Architraves may be formed out of the folid pieces; but as their formation in this way is attended with a wafte of both ftuff and time, the moft eligible method is to glue the parts longitudinally together, as is beft adapted to the nature of the mouldings. Architraves of the Grecian form, for doors and windows, generally confift of one or two faces in parallel planes, the one of which recedes only in a fmall degree from the other, while the outer edge is terminated with one or feveral mouldings which have a very prominent projection. In this cafe make a board of fufficient thicknefs, and in breadth equal to the breadth of the architrave: prepare a flip of wood of a fufficient thicknefs and breadth for the mouldings on the outer termination of the architrave; glue this flip upon the face clofe to the edge of the board, with the outer edge flufh therewith. In the operation two men will be at leaft required to rub the flip to a joint with the board; and as it often happens that the fide of the flip, which is to comply with the furface of the board, is confiderably bent, the flip is nailed down to the board; but, previoufly, fmall fquare pieces of wood, called buttons, are bored with holes, one in each, and a nail is put through the hole to the head; then the flip is alfo bored with a brad-awl; and the nails, with the pieces thus defcribed, are entered and driven home as far as the buttons will permit. The buttons may be about three quarters of an inch thick, and the other two dimenfions each equal to, or fomething more than, the breadth of the flip. The flip is fometimes grooved; and the edge of the board is tongued, glued, and inferted in the groove, inftead of the above method. Sometimes, alfo, the two faces are made of different boards tongued together at their joining; then the whole is afterwards ftuck into mouldings.

To form the furface of a cylinder with wood, whofe fibres are in planes perpendicular to the axis of the cylinder, fuch as may be ufed in circular dado, or the foffits of windows.

Method 1.—When the dimenfion of the cylindric furface, parallel to the axis, is not broader than a plank or board: this may be done by bending and gluing feveral veneers together; and the firft upon a mould or brackets, the edges of which are in the furface of the propofed cylinder parallel to its axis.

This may be accomplifhed by means of two fets of brackets fixed upon a board with hollow cylindric fpace between them, of fufficient thicknefs for taking in the veneers, and double wedges for confining them. If this operation is carefully done, and the glue properly dried, the wedges may be flackened, and the cylindric part fo glued up will be found to ftand very well; but it muft be obferved, that, as the wood has a natural tendency to unbend itfelf, the curve furface, upon which it is glued, fhould be fomewhat quicker than that intended to be made.

Some workmen take another method by forming a hollow cradle, and bending the veneers into it, and confining their ends with wedges, which comprefs them together; and by a very fmall degree of rubbing, with a hammer made for this purpofe, the glue will be forced out of the joint.

Another method is to form a cradle or templet to the intended furface, and lay a veneer upon it; then glue blocks

of wood upon the back of it, clofely fitted to its furface, and the other joints to each other, the fibres of the blocks correfponding with thofe of the veneer.

A third method is to make a cradle and place the veneers upon it, confining one end of them fpread in the glue between the veneers with a brufh, and fix a bridle acrofs, confining the ends of this bridle either by nails or by fcrews; open the veeners again, and put in glue a fecond time between each two, and fix another bridle acrofs them: proceed in this manner to the other extremity.

A fourth method is to run a number of equi-diftant grooves acrofs the back of the board at right angles to its edges, leaving only a fmall thicknefs towards the face, let this be bent round a craddle or templet made on purpofe; and let the grooves be filled with flips of wood, which, after the glue is quite dry, are to be planed down to the furface of the cylindric board, which may be ftiffened with canvas glued acrofs the back.

Inftead of ufing a grooving plane, workmen frequently make kerfs with the faw; but this is not fo ftrong when finifhed, as it is very difficult to infert the flips, and very uncertain as to the depth of each of the kerfs, which will occafion a very unequal bending of the board, if not to a regular depth.

To bend a board, fo as to form the fruftum of a cone, or any fegmental portion of the fruftum of a cone, fuch as the foffit of the head of an aperture.—Find the form of the covering according to the geometrical principles of carpentry; cut out a board to this form, and run a number of equidiftant grooves acrofs it tending to the centre: this being fixed to a templet made to the furface of a cone, proceed and finifh it in the fame manner as in the laft method fhewn for a cylinder.

To bend boards fo as to form a fpheric furface.—Make a mould to the covering of a given portion of the fphere in plano, according to the geometrical principles of carpentry; complete the number of ftaves by this mould; make a templet or mould to a great circle of the fphere; groove each of the ftaves acrofs at right angles to a line paffing through the middle, and bend it round the templet; put flips in the grooves; laftly, fhoot the edges of the ftaves, fo as to be in planes tending to the centre of the fphere: thefe ftaves being glued together will form a fpheric furface.

To glue up the fhaft of a column.—Defcribe two circles of diameters, equal to thofe of the fuperior and inferior ends of the fhaft.

Circumfcribe thefe by polygons, confifting of the fame number of regular fides as the column is to confift of ftaves.

From the angles draw lines to the centre, which will give the bevels for working the edges of the ftaves. In this procefs, after two pieces are glued together, and dried, proceed to glue a third piece in the fame manner and fo on to the laft but one. The laft, previous to being glued, the blocks fhould be fixed upon it, and then the whole may be clofed in. N. B. The number of ftaves fhould be eight or twelve, otherwife the joint will fall in the middle of the flutes, which fhould not be in the cafe. It is a very good method to diminifh the ftaves, previous to their being glued together, as otherwife the wafte of ftuff would be very great.

To glue up the bafe of a column in feveral horizontal courfes, or rings, in order to be turned in a lathe.—Confider the number of horizontal or bevel joints, which are beft made at the internal angles of mouldings; prepare a board, fo as to have a plain furface; let a circle be defcribed on the plane of a diameter, equal to the diameter of the greateft circle in the height of the courfe, and circumfcribe an equilateral polygon about the circle, with as many fides as there are to be pieces in a courfe, and from the angles draw lines towards the centre: then any radial line, and one of the adjoining fides of the polygon, will form the angle by which the ends of every two pieces that are to form the courfe will meet, fo as to make their planes coincide. The geometrical part being thus finifhed, prepare the pieces each in length equal to the fide of the polygon, with an acute angle at each end from the outer fide, equal to the aforefaid angle on the board, fo that each piece will thus have a longer and a fhorter fide: apply the longer fide of each piece to the polygon, the fhorter fide being next to the centre, fo that one of the ends may coincide with a radial; then the other end will alfo coincide, and thus the whole will meet together, if the work be true. But as this is difficult, it is common to allow the pieces to be a fmall matter longer, in order to plane them, fo as to make clofe work: for though the methods be true, the workman, though ever fo careful, cannot work to geometrical exactnefs; even the thicknefs of fhaving, or the fmalleft degree of twift in the board, will fpoil the work. Suppofe the courfe completely jointed, take the whole to pieces, and glue the furfaces which are to meet each other, and rub each two adjacent pieces to a joint, until the whole ring or courfe is firmly clofed. When the glue is dry, plane the upper fide truly; take the radius of the greateft projecting member in the next courfe, and defcribe a circle upon the top of the courfe, on the fame axis with the centre of the lower circle; and with the centre of this circle, in the plane of the top of the courfe, bifect any one of the arcs comprehended between two adjacent joints; and from the point of bifection, divide the circumference into as many equal parts as there are pieces in the under courfe, and draw radiating lines towards the centre: join every two neareft points in the circumference, and thus an infcribed polygon will be formed; draw lines to touch the circumference parallel to the fides of the infcribed polygon, and thus a polygon will be made to circumfcribe the circle: produce the radiating lines, until they meet the angles of the circumfcribing polygon; then the fides of the circumfcribing polygon will be the fituations of the bottom edge of the vertical outer fides of the fecond courfe, and the radiations the fituations of the joints. Proceed, as in the firft courfe, to adapt the pieces to their refpective fituations, making clofe work: glue each piece to its place on the lower courfe, and likewife the joints; and when the glue of this courfe is dry, its upper fide may be planed true. Proceed with the uppermoft courfe in the like manner, making the joints fall in the middle of the lengths of the pieces of the lower courfe; and when finifhed, the work may be fent to the turner.

To glue up the Ionic and Corinthian capitals for carving.—The abacus muft be glued in parts, fuch that their joints may be in vertical planes. The leaves and caulicoles of the Corinthian capital may be firft made of rectangular blocks, and fixed to the vans.

To make a cornice round a cylindric body out of the leaft quantity of wood, when the body is greater than a half cylinder, and concave, and when the members will nearly touch a right line applied tranfverfely.—Draw a fection of the cylinder through its axis, and let the fection of the cornice be reprefented upon the cylindric fection. Draw a tranfverfe line touching the two extreme members of the cornice: parallel to this line draw another line within, at fuch a diftance from the former as may be found neceffary for thicknefs of ftuff; produce this laft line, until it meet the line reprefenting the

axis of the cylinder. The junction will either be above or below, according as the cornice is applied to the convex or concave fides of the cylinder. This meeting is the centre of two concentric circles, whofe radii are the diftances between the neareft and fartheft extremes of the fection of the cornice. This is evidently an application of the method of finding the covering of a cone. When mouldings are got out in this manner, *viz.* by a piece which does not occupy the fpace, when fet to the place reprefented by the height and breadth, they are faid to be fprung.

When a cornice is to have much projection, the corona or middle part is got out of a folid piece, and the parts above and below, or one of them, as may be found neceffary, only fet to the fpring, and fupported by brackets.

To defcribe the various kinds of joinings in the practice of joinery.—*Fig.* 1. *Plate* XXII. is a fection fhewing the moft fimple method of joining boards, or any kind of framed work together at the angles; this kind of joining is much ufed in coarfe work; it is called lap-joining.

Fig. 2. the method of joining troughs together.

Fig. 3. the method of joining dado together at an internal angle.

Fig. 4. the manner of fixing two pieces of framing together at the angle of their meeting with a returned bead, in order that the joint fhould be concealed. This is only ufed in common finifhings; in good finifhings a bead of ³ths of an inch broad is generally run clofe to the joint, and the angle is left entire.

Fig. 5. fhews the common method of mitring. This form is always ufed in mouldings at an external angle, and fometimes alfo in internal angles: but for internal angles, fcribing is to be preferred, when it can be applied, which may always be the cafe, when there are no quirked mouldings; that is, when mouldings are fuch that a perpendicular line to the plane of the wall may fall upon any part of them without going through the folid of the moulding.

Fig. 6. is another method of mitring. This may be ufed in all plane furfaces, at an external angle, but is not applicable to mouldings. This manner of mitring is much more preferable in point of ftrength to that of *fig.* 5, in cafes where the two can be applied.

Dove-tailing is another mode of joining two plane furfaces together at an angle, by cutting pins of a prifmatic form and trapezoidal fection on the end of one piece, and notching the end of the other in the fame manner, fo that the exterior parts of the one is adapted to the indentations of the other, without leaving any cavity when the two fides are brought home to their places. This is the ftrongeft method of joining plane boards; it fhould always be ufed in work which may be required to be moved from place to place. There are three forts of dove-tailing. One kind, called common dove-tailing, fhews the ends of the joints: another kind, called lap-dove-tailing, conceals the joints of the dove-tails, but fhews a ftraight joint, not at the angle, but at a fmall diftance parallel to it. The third fort is called mitre dove-tailing, which fhews no joint but in the angle. This method is very neat, it is ftronger than the ftraight joint fhewn by the fection *fig.* 6, and where both ftrength and beauty is required it muft be preferred to any other. *Fig.* 7, N 1, is a fection of common dove-tailing; N 2, the fide of one of the pieces fhewing the pins; N 3, fhews the ends of the pins; N 4. the fide of the other piece, fhewing the indentations for receiving the pins.

Fig 8. N 1, 2, 3, 4, and 5, different parts of mitre dove-tailing.

To join two pieces of wood together, the fibres of the one running tranfverfely to the fibres of the other by mortife and tenon or dove-tailing.—One method is by cutting a mortife to a very fmall depth in the one piece, and a tenon of the fame length in the other, and by bolting them together with one or two bolts: where the breadth of the piece having the tenon is confiderable, the nuts are to be let in from that fide of the tenoned piece which is not expofed to fight; the heads of the bolts upon the mortifed piece may be funk into the wood entirely below the furface, and the cavity may be filled up with a piece of the fame kind of wood, neatly fitted in.

Definitions.—1. A frame, in joinery, is the connection of feveral pieces of timber of an equal thicknefs, joined tranfverfely to each other, made faft by means of mortifes and tenons, leaving rectangular fpaces between for other pieces of timber, called pannels, each of which is inferted into each edge of the former by means of a groove.

2. Thofe parts of the frame which terminate the two vertical extremes are called ftyles.

3. The horizontal parts, which are mortifed into the ftyles, are called rails.

4. If there be any intermediate pieces mortifed into the rails, parallel to the ftyles, fuch pieces are called muntons.

In framed-work, rails have feveral epithets, according to their fituations; that bordering the framing at the lower extremity is called the bottom rail, that bordering the framing, at the other extremity, is called the top rail. The names of intermediate rails vary according to their number and fituation. In doors, that in which the lock is inferted is called the middle, or lock rail; the intermediate rail next to the top rail, is called the frieze rail.

Doors.—A door, in joinery, is a framed piece of timber-work, or boards nailed together, for the purpofe of fhutting up at pleafure any aperture in a wall or partition, in order to give or prevent paffage from one apartment to another.

Plate XXIII. *fig.* 1, is a four equal-pannelled door: the form is only ufed in very common work, and is frequently without mouldings.

Fig. 2. is a nine-pannelled door, with fquare pannels at the top. This form is frequently ufed in ftreet-doors, of which the back is often lined with boards, in the manner of *fig.* 3, flufh with the ftyles and top rail; the other rails and muntons muft therefore be receffed upon one fide to receive the boarding.

Fig. 4. is a fix equal-pannelled pair of folding-doors, having two pannels in the breadth.

Fig. 5. is a double margin, or a pair of folding-doors, with four pannels in height, and two in breadth, having lying pannels below the top-rail, and above the lock-rail.

Fig. 6. is a ten-pannelled pair of folding-doors, five in height, and two in breadth, having lying pannels at the top, bottom, and in the middle, with long pannels between them. Of this form is the ancient door of the Pantheon at Rome.

Fig 7. a fafh-door: this form, if not fhut with another feparate door, fhould have fhifting-fhutters, to cover the glafs parts, fixed with bolts and nuts. For this purpofe, it fhould at leaft be one inch and a quarter thicker than a pannelled door in the fame place: this gives room for the outfide of the fhutter to be flufh with the ftyles of the door; but if otherwife, an ugly frame muft be patched round the glazed parts, in order to contain the fhutter.

Fig. 8. an ancient door, of which form are the windows and door of the temple of Vefta at Rome, and alfo thofe of the temple of Eretheus at Athens.

Figs. 9 and 10. are doors of communication, or fuch as, when open, will not encumber the floor, as other kinds of receffed doors, by jetting into the room, but may either be

concealed entirely within the partition, or folded clofe to it: they are ufed for the purpofe of making a free communication between one room and another, at great meetings or balls, when any one of the rooms would be infufficient though large enough for common ufe.

Fig. 9. the elevation of a door to be folded clofe to the partition, by means of a hanging ftyle, or pilafter, on each fide which is firft hung to the jamb, then a folding door to each pilafter.

Fig. 10. is a door confifting of four parts: each middle part is hinged to each extreme part; each two parts, on each fide, in time of company, may be removed entirely out of the way into hollows on each fide of the partition, and guided by grooves at the top and bottom, and made to flide freely upon rollers.

Fig. 11. is a jib-door, that is, fuch a door as, when fhut, may be as much concealed as poffible from having the appearance of a door. Jib-doors are ufed, when only one aperture at the end of the fide of a room is neceffary; and when it is required to keep the fymmetry of that fide, without having the appearance of a door; the bafe, furbafe, and paper are, therefore, continued over it as in the other parts of the room, the joint being only feen at the top, and upon the edge oppofite the hinge.

Iron

IRON, *Eiſen*, Germ. *Fer*, Fr. *Ferrum*, Lat. *Ferro*, Ital. *Jeren*, Swed. *Jernet*, Dan. *Vas*, Hung. *Hierro*, Span. *Julazo*, Ruſſ. *Ferro*, Port Σιδηρο, Gr. בַּרְזֶל (*Bharzel*, or *Varzel*), Heb. *Mars*, Alchem.

The uſe of this metal is of very high antiquity, though not ſo remote, there is reaſon to believe, as that of either gold, ſilver, or copper. The inferior brilliancy of its colour may, perhaps, in ſome degree, account for this circumſtance; as well as the greater ſkill required to obtain it from its ores, and convert it to the purpoſes of art. It is mentioned frequently in the pentateuch; and was, in the time of the celebrated writer of that hiſtory, employed for the fabrication of ſwords, knives, and various other ſharp-edged inſtruments. We may form ſome eſtimate of the value that was then attached to it, from an expreſſion in the eighth chapter of Deuteronomy, where Moſes tells the Iſraelites, in his deſcriptive eulogy of the Land of Promiſe, that it is "a land whoſe ſtones are iron, and out of whoſe hills" they may "dig braſs." A circumſtance, illuſtrative of the ſame fact, at a later date, is furniſhed about 400 years ſubſequent to that period, when Achilles propoſed a ball of iron as one of the prizes to be diſtributed to the victors at the games inſtituted in honour of Patroclus. (Ιλιαδος, Ψ.) The art of working it appears, in the courſe of a few ſucceeding centuries, to have arrived at conſiderable perfection; for, according to the information of Herodotus (Clio xxv.), a ſaucer of the metal, very curiouſly inlayed, was preſented by Alyattes, king of Lydia, to the Delphic oracle, which, he ſays, "is of ſurpriſing workmanſhip, and as worthy of obſervation as any of the offerings preſerved at Delphi." The durability of iron, and its indiſpenſible aſſiſtance in the preparation of every other metal, make it one of the moſt valuable poſſeſſions that has been bequeathed to the uſe of civilized man. "Without it," obſerves Fourcroy, "agriculture could not have exiſted, nor could the plough have rendered the earth fertile. The philoſopher, while he ſtudies the progreſs of the human underſtanding, and compares the fortune and ſtate of the different nations eſtabliſhed on various portions of the ſurface of the globe, will remark, that their iron-works ſeem, in ſome meaſure, to be proportioned to their intelligence, to the advancement of reaſon amongſt them, and the degree of perfection to which the arts have arrived. When we conſider it in this point of view, as the agent by which men, in the variety of its uſes, and the numerous wants it ſupplies, acquire enjoyments which would be unknown to them if they did not poſſeſs theſe products of their induſtry, iron muſt ſingularly contribute to extend their ideas, to multiply their knowledge, and to conduct their ſpirit towards that perfectibility, which nature has given no leſs, as the character of the human ſpecies, than as the ſource of all the advantages it can enjoy." Syſt. vol. 6.

Iron is a malleable and ductile metal, of a blueiſh-white colour; is ſuſceptible of a very high poliſh, and of the ſpecific gravity, according to the tables of Muſchenbroeck, Swedenburg, and Briſſon, of from 7.600 to 7.895, and even 8.166. It is ſoluble in moſt acids, and precipitable from its combination with them, by various re-agents, which will be hereafter pointed out. With the Pruſſic acid it forms that beautiful pigment known in commerce, and the arts, by the name of *Pruſſian blue;* and in a variety of other ways, conſtitutes the baſis of many valuable preparations. The combinations under which it is exhibited to us in nature are detailed in the following ſection.

§ 1. *Ores of Iron.*

Sp. 1. *Native iron. Gediegen-eiſen. Fer natif. Ferrum nativum.*

Its colour is ſteel-grey, paſſing to ſilver-white. Occurs only in a ramoſe form; the maſſes alluded to by Brochant and others being now conſidered of meteoric origin. Surface gliſtening. Internally it is intermediate between gliſtening and glimmering; and its luſtre metallic. Fracture hackly. It is rather ſoft, is completely malleable, and flexible without being elaſtic. Sp. gr. 7.8.

A ſpecimen from a mine near Kamſdorf, in Saxony, yielded, according to Klaproth,

Iron	92.5
Lead	6.0
Copper	1.5
	100.0

The varieties which contain nickel are meteoric.

It is found in detached maſſes, which are uſually covered with an oxyd of a browniſh colour.

The places of its occurrence are Kamſdorf and Eibenſtock, in Saxony; Oulle, near Grenoble, in France; and ſome others.

Sp. 2. *Iron Pyrites. Schwefelkies. La Pyrite Sulfureuſe. Ferrum Mineraliſatum Pyrites.*

This very abundant mineral is divided by Werner into five ſubſpecies, common, radiated, capillary, hepatic, and cellular.

Subſp. 1. *Common Pyrites.*—Colour bronze-yellow, paſſing ſometimes to gold-yellow. Occurs maſſive and diſſeminated. It is very frequently alſo cryſtallized. Its forms are the cube, either perfect or truncated, the octahedron, dodecahedron, and ſometimes, though very rarely, the icoſahedron. The cryſtals are in general ſmall; except the cube, which is middle-ſized. Their ſurface is either ſmooth or ſtreaked, and varies from glimmering to ſplendent. Internally it is ſhining or gliſtening; and its luſtre metallic. Fracture even; ſometimes conchoidal. It is hard, brittle, rather eaſily frangible, and heavy. Sp. gr. from 4.600 to 4.831.

Expoſed to the blow-pipe, it exhales a ſtrong odour of ſulphur, and burns with a blueiſh flame. It afterwards paſſes into a globule, obedient to the magnet, of a browniſh colour; and treated with glaſs of borax, communicates to it a tint of a dark dirty green. It appears to be compoſed of about 52.5 ſulphur, and 47.5 iron.

Its occurrence is almoſt univerſal, both with reference to geographic arrangement, and the mineral formations in which it is preſented.

Subſp. 2. *Radiated Pyrites.*—Colour bronze-yellow, of a paler hue than the preceding; paſſing ſometimes to braſs-yellow. Surface tarniſhed. Is found maſſive and reniform, alſo uniform, globular, and cryſtallized. The ſhape of its cryſtals is cubic, and octahedral; the latter being ſometimes truncated on the angles. The external luſtre varies between ſplendent and gliſtening. Internally it is gliſtening and glimmering. Fracture uſually radiated; ſometimes uneven and fibrous. Fragments uniform. Occurs in coarſe and large-grained diſtinct concretions, alſo lamellated and columnar. It is hard, brittle, very eaſily frangible, and heavy, but leſs ſo than the foregoing ſubſpecies. Emits a ſulphureous odour when ſtruck, or rubbed. Sp. gr. from 4.698 to 4.775.

Before the blow-pipe it exhibits the ſame appearances as common pyrites, and is conſtituted of about 54 parts of ſulphur, and 46 of iron.

It is conſiderably rarer than the preceding, and is found in veins, particularly thoſe which contain lead or ſilver.

The places of its occurrence are, amongſt others, Cornwall and Derbyſhire, in England; Arendal, in Norway; and in various diſtricts of Suabia, Saxony, and Bohemia.

Subſp. 3. *Capillary Pyrites.*—Colour bronze-yellow, inclining more or leſs to ſteel-grey. Occurs in very fine capillary cryſtals. Luſtre ſhining or gliſtening; metallic. Brittle, and in a ſmall degree flexible. The ſmallneſs of its cryſtals prevents a more particular account being given of its character.

Its chemical properties are the ſame as thoſe of common pyrites.

It is never met with but in very ſmall quantity, and is the moſt rare of all the varieties of pyritic iron. It is moſt uſually accompanied with quartz, lead-glance, or galena, and fluor and calcareous ſpar.

Is found at Annaberg, Schneeberg, and Johanngeorgenſtadt, in Saxony; at Andreaſberg, in the Hartz; and other places on the continent of Europe. The capillary pyrites, according to Klaproth's analyſis, is not an iron-ore, but nickel, mixed with a ſmall portion of cobalt and arſenic.

Subſp. 4. *Hepatic Pyrites.*—Its colour is intermediate between bronze-yellow and ſteel-grey, paſſing ſometimes entirely to the latter. On expoſure, the freſh fracture changes to a brown. It is found maſſive, and under a variety of other forms, as ſtalactitic, cellular, &c. alſo cryſtallized. The ſhape of its cryſtalline arrangement is priſmatic, pyramidal, and tabular, each with ſix ſides. Luſtre glimmering, inclining to gliſtening; metallic. Fracture even, paſſing ſometimes to uneven and imperfectly conchoidal. Fragments indeterminate, ſharp-edged. Hard, rather inclining to ſoft, brittle, eaſily frangible, and heavy.

This ſubſpecies is ſaid to contain arſenic. It decompoſes very eaſily on expoſure to air, which renders it very difficult to be retained in mineralogical collections.

It occurs only in veins, and in thoſe principally which contain red ſilver ore, galena, blende, common pyrites, and ſparry iron-ſtone. The earthy minerals that acccompany it are, for the moſt part, quartz, ſulphat of baryt, and calcareous and fluor ſpar.

It is found in Derbyſhire; at Joachimſthal in Bohemia; Annaberg and Freyberg in Saxony; and in various parts of Sweden, Norway, and Siberia.

Subſp. 5. *Cellular Pyrites.*—Colour bronze-yellow, a good deal inclining to ſteel-grey. Tarniſhes by expoſure, and then becomes of a grey tint. Occurs maſſive; but its moſt common appearance is cellular. Cells druſy on the ſurface. Luſtre gliſtening. Fracture conchoidal. Fragments ſharp-edged, indeterminate. Brittle, and in a ſlight degree flexible.

Its occurrence is in veins, where it is accompanied, according to the ſtatement of profeſſor Jamieſon, with hepatic and common pyrites, lead-glance, ſparry iron-ſtone, nickel, iron-ochre, brown-ſpar, heavy-ſpar, fluor-ſpar, and quartz.

Is found at Johanngeorgenſtadt, in the electorate of Saxony.

Sp. 3. *Magnetic Pyrites. Magnetkies. La Pyrite magnetique. Ferrum mineraliſatum magnetico pyritaceum.*

Colour copper-red, inclining much to bronze-yellow, and even to pinchbeck-brown. Tarniſhes on expoſure, becoming then brown. Occurs maſſive and diſſeminated: has never been found under any other form. Internal luſtre gliſtening, or ſhining; metallic. Fracture uneven, and ſometimes imperfectly conchoidal: when the latter, it has a luſtre bordering on ſplendent. Fragments indeterminate, rather blunt-edged. Intermediate between hard and ſemi-hard. It is brittle, eaſily frangible, and very heavy. Is attracted by the magnet. Sp. gr. 4.516.

Treated by the blow-pipe, it emits a ſlight ſulphureous odour, and melts with great facility into a greyiſh-black globule, which is attracted by the magnet, and colours borax black. It is compoſed of 36.5 ſulphur, and 63.5 iron.

It occurs only in the claſs of rocks denominated primitive; and there only in beds. The minerals which uſually

accompany it are galena, magnetic iron-ftone, arfenical pyrites and tin-ftone; with alfo quartz, garnet, ftrahlftein, hornblende, &c.

Its geographic diftribution is rather extenfive. Amongft many other inftances, the following may be enumerated: Moel Elion, in Caernarvonfhire, North Wales; Geyer, Breitenbrunn, &c. in Saxony; Bodenmais, in Bavaria; and in different parts of Norway and Siberia.

Sp. 4. *Magnetic Iron-ftone. Magneteifenftein. Le fer magnetique. Ferrum magnes.*

Werner divides this into two fubfpecies; namely, common magnetic iron-ftone, and magnetic iron-fand.

Subfp. 1.—*Magnetic Iron-ftone.*—Colour iron-black, inclining fometimes to perfect black, and fometimes to fteel-grey. Occurs maffive, diffeminated and cryftallized. The form of its cryftals is the cube, perfect or truncated; the octahedron, which is alfo fometimes varied by truncation; the garnet dodecahedron, and the rectangular four-fided prifm, terminated by four planes, placed on the lateral edges, as in the hyacinth. Thefe cryftals vary much in fize. The dodecahedrons and octahedrons have their faces fmooth; but the planes of the four-fided prifm are tranfverfely ftreaked. Luftre externally fhining; internally varying from glimmering to fplendent. Fracture fmall and fine-grained, uneven, approaching fometimes to fmall conchoidal, and imperfect foliated. Fragments indeterminate, rather fharp-edged. Occurs fometimes in granular diftinct concretions. It is femi-hard, paffing to hard; brittle; when in cryftals difficultly frangible, and heavy. Sp. gr. 4.200 to 4.939. It is attracted by the magnet; and is itfelf alfo magnetic.

Before the blow-pipe it becomes brown, and imparts a dark-green colour to borax. It is fuppofed to be an oxyd of iron, nearly in a ftate of complete purity.

This fpecies is very common in primitive mountains, efpecially in thofe of gneifs and micaceous fchiftus. In thefe fituations it arranges itfelf in beds; but fometimes compofes the entire mafs of diftinct mountains. The fletz, or fecondary formations, as they are termed, are not free from it. It occurs in greenftone at Taberg; in hornblende in Smoland, and in bafalt near Eifenach. It is ufually affociated with common hornblende, garnet, and granular limeftone. Sometimes with actinote, afbeft, &c.; but is moft frequently found in the vicinity of magnetic pyrites, arfenical and copper pyrites, and common pyrites.

It is found in one of the Shetland ifles; in Bohemia, Hungary, Saxony, Italy, France, Switzerland, Siberia, and South America. Is very abundant in Sweden, where it is employed for the manufacture of the iron imported to this country for the fupply of the Sheffield market.

Subfp. 2. *Iron-fand.*—Colour deep iron-black, which paffes fometimes to afh-grey. Occurs in angular or roundifh grains; and alfo in fmall octahedral cryftals. Surface rough and feebly glimmering. Internal luftre fhining, metallic. Fracture perfect conchoidal. Fragments indeterminate, fharp-edged. Streak greyifh-black. Semi-hard, brittle, eafily frangible, and heavy. Sp. gr. 4.600. Strongly attracted by the magnet.

Its chemical characters are as the foregoing fubfpecies.

It occurs in the beds of rivers; and alfo imbedded in the rocks of bafalt and wacke.

Is met with in the river Elbe, near Schandau, in Saxony; imbedded in floetz-trap, in Bohemia; and is found alfo at St. Domingo, Guadaloupe, in Norway, France, the Tyrol, Greenland, &c.

Sp. 5. *Iron-glance. Eifenglanz. Le fer fpeculaire. Ferrum mineralifatum fpeculare.*

This is alfo divided into two fubfpecies; common iron glance, and micaceous iron-ore, or, as it is called by profeffor Jamefon, iron-mica.

Subfp. 1. *Common Iron-glance.*—Colour fteel-grey of greater or lefs intenfity, and fometimes reddifh. It occafionally paffes into iron-black. Surface very often tarnifhed, and beautifully iridefcent. Occurs maffive, diffeminated, and cryftallized. The form of its cryftals is various. The moft common is the rhomboidal parallelopipedon; the cube, formed by the truncation of a double three-fided pyramid, and having three triangular faces inftead of two of its angles oppofite, and octagonal plates bounded by linear trapeziums, fix in number, inclined alternately to different fides. Planes of the cryftals fometimes fmooth, and fometimes ftreaked. Externally it varies from glimmering to fplendent; internally from gliftening to fplendent; luftre metallic. Fracture compact and foliated. The compact varieties are uneven, and fometimes fmall conchoidal. The foliated have a fourfold rectangular cleavage. Fragments octahedral or pyramidal; fometimes indeterminate. Edges rather blunt. Generally unfeparated. Gives a deep cherry-red ftreak. It is hard, opaque, brittle, more or lefs eafily frangible, and heavy. Sp. gr. 5.0116 to 5.218. It is magnetic, but lefs fo than the preceding fpecies.

Before the blow-pipe it is infufible, alone; but becomes white when heated on charcoal; and yields a dirty yellow-coloured fcoria, with borax. Stated by Kirwan to contain from 60 to 80 *per cent.* of iron.

This fpecies appears to be confined to primitive, and the clafs called tranfition mountains. It has never been found in thofe of fecondary formation. Its occurrence is in beds and veins, where it is ufually accompanied with magnetic iron-ftone, common pyrites, compact red iron-ftone, hornftone, and quartz.

Sweden yields it very abundantly; as alfo does Norway. Some of the fineft fpecimens are from the ifle of Elba, where the ore is faid to have been worked for upwards of three thoufand years. It occurs in Bohemia, Saxony, Switzerland, France, England (in Lancafhire and Cumberland), Hungary, South America, Siberia, &c.

The Englifh fpecimens occur in cavities in compact red iron-ftone. The cryftals are ufually fmall; and the luftre of their furface is particularly fplendent.

Subfp. 2. *Iron-mica.*—Colour iron-black, paffing fometimes to fteel-grey, and fometimes to deep-red. The latter is rather the colour of it, when held under the form of thin plates, between the eye and the light. Occurs maffive, diffeminated, and cryftallized. When the latter, it appears in thin tables with fix fides. Surface fmooth and fplendent. Internally it is alfo fplendent, and its luftre metallic. Fracture perfect curved foliated; cleavage fimple. Fragments fometimes indeterminate, and fometimes tabular. The maffive varieties occur in granular diftinct concretions. Thin plates of it are tranflucent. Its ftreak is deep cherry-red. It is femi-hard, brittle, very eafily frangible, and heavy. Sp gr. 4.50 to 5.07.

Before the blow-pipe it exhibits the fame appearances as the preceding fubfpecies, except in communicating an olive-green tinge to borax. The proportion of iron which it yields is from 70 to 80 *per cent.*

It is exclufively confined to primitive mountains, and for the moft part to thofe of a newer formation. It is found, like iron-glance, in beds and veins, and is accompanied with other ores of the metal: calcareous and fluor fpar, quartz, hornftone, &c.

Its geographic diftribution is rather extenfive. It occurs near Dunkeld, in Perthfhire; at Dartmoor, in Devonfhire;

in one of the Shetland isles; in Norway, Sweden, Russia, France, isle of Elba, and many districts of Germany.

Sp. 6. *Red Iron-stone. Roth-eisen stein. La mine de fer rouge. Ferrum ochraceum rubrum.*

Werner has divided this into four subspecies, which professor Jameson, in conformity with the principles of the Wernerian nomenclature, has denominated red iron-froth, ochry-red iron-stone, compact red iron-stone, and red hematite.

Subsp. 1. *Red Iron-froth.*—Colour deep cherry-red, sometimes blood-red and brownish-red, and even inclining to steel-grey. Usually friable. Occurs sometimes massive and disseminated; and is composed of scaly parts which soil considerably. Lustre between glimmering and glistening; semi-metallic. Is greasy to the touch, and moderately heavy.

Exposed to the blow-pipe alone, it blackens without melting, and communicates a bright green colour to borax. According to Hauy, it is constituted of

Iron	66.
Oxygen	28.5
Silex	4.25
Alumine	1.25
	100.

It occurs generally in veins in primitive and transition mountains, accompanied with other ores of iron, copper pyrites, quartz, barytic spar, &c.

Although a rare variety of this metal, it is found rather plentifully in the neighbourhood of Ulverstone, Lancashire, and is also met with in Cornwall. It occurs too in Norway, the Hartz, Saxony, Silesia, Salzburg, Hungary, and South America.

Subsp. 2. *Ochry-red Iron-stone, or Red Ochre.*—Colour varies between blood-red and brownish-red. Occurs sometimes massive and disseminated, sometimes superficial, or coating other ores of the metal, but most usually friable. Lustre faintly glimmering, or dull. Fracture earthy. Fragments indeterminate, blunt-edged. Feels meagre. Soils more or less strongly. Is not very brittle. Easily frangible, and rather heavy. Sp. gr. 2.952.

It is rarely found alone; being generally accompanied with other species of iron-ore, and particularly with compact red iron-stone, and red hematite. It occurs in veins; and is distributed nearly as the two following subspecies.

Subsp. 3. *Compact red Iron-stone.*—Colour between brownish-red and dark steel-grey, passing sometimes to blood-red. Occurs massive, disseminated, and in various imitative forms, as reniform, cellular, &c. It is sometimes found crystallized, and appears either in cubes, or four-sided pyramids, the latter of which are truncated on their summits. The cube is found both perfect and truncated. Surface of the cubes smooth; of the pyramids rough and dull. Internal lustre between glimmering and dull; semi-metallic. Fracture for the most part even. It sometimes, however, passes into coarse-grained, uneven, and large conchoidal. Fragments indeterminate, rather sharp-edged. Streak blood-red. Between hard and semi-hard. Somewhat brittle, and more or less easily frangible, heavy. Sp. gr. 3.423 to 3.76.

It assumes a darker colour before the blow-pipe; but is infusible, even with the assistance of borax. This re-agent, however, is tinged of a yellowish-green by it.

Occurs in beds and veins with red hematite and the preceding subspecies; and is also accompanied with quartz, red-jasper, and hornstone.

It is found very abundantly in Lancashire; in the Hartz, Saxony, Bohemia, Hessia, Siberia, and France.

It is frequently smelted in this country; and principally in those works which fabricate the variety of iron described in the succeeding part of this article, under the name of *forge-pig*. The richer ores, in fact, are incapable of yielding the most highly carbonized descriptions of iron; partly, perhaps, because they contain too little earthy matter to afford a sufficiently plentiful *cinder;* and partly because their reduction is too immediate.

Subsp. 4. *Red Hæmatite.*—Colour intermediate between brownish-red and steel-grey; passing sometimes intirely into one or other of them, and even into blood-red. It is from the latter variety that the name of hematite (from αιμα, *sanguis,*) is derived. Occurs massive and reniform; also stalactitic, globular, uniform, &c. External surface rough and glimmering Internally glistening, passing into glimmering; lustre semi-metallic. Fracture always fibrous. Fragments usually wedge-shaped; sometimes splintery and indeterminate. In angulo-granular distinct concretions. Streak a bright blood-red. Hard, inclining to semi-hard. Rather difficultly frangible. Brittle, and very heavy. Sp. gr. 4.74 to 5.005.

It exhibits the same chemical characters as the foregoing subspecies, and yields in the large way about 60 *per cent.* of metal.

According to the recent analysis of M. D'Aubuisson, who has published a very interesting memoir in the 75th volume of the "Annales de Chimie," on the chemical constitution of certain iron ores which appear to have water as an essential ingredient, this mineral is composed of

Peroxyd of iron -	90
Silex - -	2
Lime - -	1
Volatile matter -	3
Loss - -	4
	100

The specific gravity of the specimens here submitted to examination was 4.8. Another specimen, the specific gravity of which was 5.0, yielded the following result:

Peroyxd of iron -	94
Silex - -	2
Water - -	2
Loss - -	2
	100

Each of the above presented a trace of manganese, and the latter a similar evidence of lime.

Its geognostic situation is similar to the last.

Lancashire yields it very plentifully, as well as the neighbouring parts of Cumberland. It is found, too, in considerable abundance in Saxony; and in Bohemia, France, Silesia, the Hartz, Siberia, &c.

It is one of the most common varieties of iron ore, and is very frequently employed in the smelting furnace.

Sp. 7. *Brown Iron-stone. Brown Eisenstein. La mine de fer brune. Ferrum ochraceum brunum.*

This, like the preceding, is divided into four subspecies, which have the same leading distinctions. They consist of brown iron-froth, ochry-brown iron-stone, compact brown iron-stone, and brown hematite.

Subſp. 1. *Brown Iron-froth.*—Colour varying between clove-brown and ſteel-grey. Occurs maſſive, ſuperficial, and frothy. Is compoſed of ſcaly particles, which are gliſtening, and have a metallic luſtre. Fragments indeterminate, blunt-edged. Intermediate between friable and ſolid. Soils ſtrongly. Feels greaſy to the touch. Is very ſoft, light, and ſometimes even ſwimming.

It blackens before the blow-pipe without melting, and communicates a yellowiſh-green colour to borax.

It is generally found coating compact brown iron-ſtone, and brown hematite.

One of the Shetland iſlands affords it; and it occurs alſo in Saxony, the Hartz, Norway, Carinthia, Bareuth, Carniola, and Stiria.

Subſp. 2. *Ochry-brown Iron-ſtone.*—Colour yellowiſh-brown, inclining to ochre yellow. Occurs maſſive and diſſeminated. Between ſolid and friable. Fracture earthy. Internally it is dull. Fragments indeterminate, blunt-edged. Soils conſiderably. Is more or leſs coherent, and heavy.

Imparts an olive-green colour to borax.

It accompanies the other ſubſpecies; and is found in Norway, Saxony, Bohemia, Bavaria, and Salzburg.

Subſp. 3. *Compact Brown Iron-ſtone.*—Colour clove-brown of various intenſities, paſſing ſometimes to yellowiſh-brown. Occurs maſſive, diſſeminated, and in various imitative forms, as ſtalactitic, reniform, cellular, dendritic, &c. It ſometimes, alſo, appears in pſeudo-cryſtals, of which the cube, rhomb, and lens have been particularized. Madrepores and corallines, too, have it frequently for their baſe; as well as other extraneous foſſils. Internally it is dull, or very rarely glimmering. Fracture uſually even, ſometimes earthy and ſmall-grained uneven, and conchoidal. Fragments indeterminate, edges more or leſs blunt. Streak bright yellowiſh-brown, bordering on ochre-yellow. Is ſemi-hard, inclining to hard. Rather brittle. Eaſily frangible, and heavy. Sp. gr 3.4771 to 3.551.

It darkens before the blow-pipe, in conſequence of the loſs of oxygen, and becomes magnetic. Borax receives an olive-green colour from it.

The proportion of its ingredients, as ſtated by M. D'Aubuiſſon, in the 75th volume of the "Annales de Chimie," is as follows:

	From Bergzabern.	From Vicdeſſos.	From Voightſberg.
Peroxyd of iron -	84	81	69
Peroxyd of mangancſe	1		3
Silex - -	2	4	10
Alumine - -	,		3
Volatile matter -	11	12	13
Loſs - -	2	3	2
			100

The ſpecific gravity of the ſpecimen from Vicdeſſos was 3.4.

It is always accompanied with ſome of the other ſubſpecies; and frequently with quartz, calcareous and heavy ſpar, and pyrites.

Occurs in Mainland, one of the Shetland iſles; the Hartz, Saxony, Sileſia, Bohemia, Suabia, the Tyrol, France, Carinthia, &c.

Subſp. 4. *Brown Hematite.*—Its colour, internally, is clove-brown, which paſſes to yellowiſh-brown, and browniſh-black. It is exhibited under a great variety of other ſhades, as blueiſh or iron-black, pinchback-brown, bronze-yellow, and ſometimes irideſcent. Occurs rarely maſſive; uſually in ſome of the imitative forms before ſpoken of. It is ſometimes found in pſeudo-cryſtals of a pyramidal ſhape, with ſix acute-angled ſides. Surface ſometimes ſmooth, and ſometimes rough and druſy. Luſtre ſhining or gliſtening. Internally it is from glimmering to gliſtening; intermediate between ſilky and reſinous. Fracture fibrous, paſſing ſometimes to ſmall conchoidal. Fragments uſually ſplintery or wedge-ſhaped; rarely indeterminate. Occurs in diſtinct concretions. Streak yellowiſh-brown. Opaque. Semi-hard. Brittle. Very eaſily frangible, and heavy. Sp. gr. 3.789 to 3.951.

It blackens before the blow-pipe, but does not melt. With borax it enters into ebullition, and produces a dirty yellow-coloured compound.

Its conſtituent parts, according to M. D'Aubuiſſon, whoſe analyſes were generally repeated two or three times, are as below ſtated:

	From Bergzabern.	From Vicdeſſos.
Peroxyd of iron - -	79	82
Peroxyd of mangancſe -	2	2
Silex - - -	3	1
Volatile matter - -	15	14
Loſs - - - -	1	1
	100	100

The ſpecific gravity of the former was 3.8, and of the latter 3.9. The ſpecimen from Vicdeſſos afforded a ſlight trace of alumine.

It occurs in the neweſt primitive, tranſition, and ſecondary mountains; but moſt frequently in the two latter, where it is found lining cavities in veins or beds. Its uſual attendants are black and ſparry iron-ſtone, calcareous ſpar, brown and heavy-ſpar, and ſometimes, though rarely, quartz.

It is found in Voightland, the Fichtelgebirge, Franconia, Heſſia, and Naſſau.

This ſpecies, which is ſo very abundantly diſtributed in the German ſtates, is of rare occurrence either in Sweden, Ruſſia, Norway, or England. In the former, it furniſhes materials for very extenſive iron-works; and the wrought-iron produced from it is very valuable.

Sp. 8. *Sparry iron-ſtone. Spath eiſenſtein. Le fer ſpathique. Ferrum ochraceum ſpatiforme.*

Colour yellowiſh-grey, which paſſes into yellowiſh-brown, clove-brown, and blackiſh-brown. It tarniſhes on expoſure either to the air or heat, and then becomes brown or black, and ſometimes irideſcent. Occurs maſſive, diſſeminated, and cryſtallized. Its cryſtals are either rhombs, lenſes, octahedrons, or garnet-dodecahedrons. They are ſeldom large or very ſmall; commonly middle-ſized and ſmall. Their ſurface is ſometimes ſmooth, ſometimes druſy, and a little rough. Internally it varies from ſplendent to glimmering; luſtre pearly. Fracture foliated. Cleavage triple. Fragments rhomboidal. Occurs in granular diſtinct concretions. The light-coloured varieties are tranſlucent, eſpecially on the edges; but the dark-coloured opaque. The former give a greyiſh-white ſtreak; the latter a yellowiſh brown. It is ſemi-hard, inclining ſometimes to ſoft. Rather brittle. Eaſily frangible, and moderately heavy. Sp. gr. 3.300 to 3.810.

It blackens before the blow-pipe, and enters into ebullition with borax, to which it communicates a dirty yellow colour. It always effervesces more or leſs with acids. According to Bergman, it is compoſed of

Oxyd of iron -	38
Oxyd of manganefe	24
Lime - -	19
Carbonic acid -	10
Water -	9
	100

but it is liable to great variation in the proportion of its ingredients. In a recent examination by Collet-Defcotils, the following refult was afforded:

Fragments of quartz -	2.58
Red oxyd of iron -	48.45
Brown oxyd of manganefe	1.80
Lime	52
Magnefia	1.98
Carbonic acid, water, and lofs	44.67
	100.

Annales de Chimie, t. 58.

The fpecific gravity of the fpecimen analyfed in this cafe was 3.693; and its colour was brownifh-yellow.

It occurs in primitive and fecondary mountains; in the former, in veins; in the latter, in beds.

It is found fparingly in Britain; and not very abundantly in Sweden, Norway, Switzerland, Siberia, Bohemia, and Saxony. At Schmalkalden, in Heffia, however, there is a bed from 25 to 30 fathoms thick; and in different parts of Weftphalia, Stiria, Carinthia, &c. it is very plentiful. A whole hill, in the province of Bifcay, is compofed of it, which is faid to have been worked for feveral thoufand years.

It is much ufed as an ore of iron, and the metal produced from it is confidered to be peculiarly favourable for fteel-making; but whether this is any thing more than a mere prejudice, feems greatly to be queftioned.

Sp. 9. *Black iron-ftone. Schwarz eifenftein. La mine de fer noire. Ferrum ochraceum nigrum.*

This is divided into two fub-fpecies; compact black iron-ftone, and black hematite.

Subfp. 1. *Compact Black Iron-ftone.*—Colour between blueifh-black, and dark fteel-grey. Occurs maffive, and in various imitative forms. Surface dull, or faintly glimmering. Internally it is bordering on gliftening, and its luftre femi-metallic. Fracture commonly conchoidal, fometimes uneven. Fragments indeterminate, fharp-edged. Streak fhining, but unchanged. It is femi-hard, brittle, eafily frangible, and heavy. Sp. gr. 4 076, according to Wiedemann.

This mineral had for a long time been claffed as an ore of manganefe, and was removed to the prefent genus from fome particular diftinctions that were pointed out by Werner, between the compact grey manganefe ore, of which it had ufually been confidered a variety, and the fub-fpecies now under examination. M. D'Aubuiffon, however, in the courfe of his late refearches, has fubjected a fpecimen of it to chemical analyfis; and inftead of finding iron to be its principal ingredient, has afcertained it to be almoft wholly compofed of manganefe and filex. This would, perhaps, be a fufficient authority for transferring it to the latter genus again; but as the Wernerian claffification has been uniformly adhered to in the prefent article, it has been deemed beft to continue its enumeration here, and accompany the account of it with the particulars of M. D'Aubuiffon's inquiry.

The fpecimen he examined came from Rafchau, in Saxony, and was of a blueifh-black colour mixed with grey. It had a compact fracture, was femi-hard, approaching to hard, and of the fpecific gravity of 3.6. It confifted of

Peroxyd of manganefe - -	64
Silex - - - -	13
Volatile matter - -	14
Lofs (occafioned by an accident in drying fome carbonat of manganefe on the filter) - -	9
	100

Annales de Chimie, t. 75.

Confiderable difference is very likely to exift in the chemical conftitution of this mineral, and the total abfence of iron, in the prefent cafe, may certainly be regarded as rather an extraordinary circumftance. Indeed, Werner's judgment is much too accurate to admit the fuppofition, that the varieties which have come under his infpection were deftitute of it; but from the very great produce of manganefe in the above analyfis, and the general character of the fpecies, in imparting a violet-blue colour to borax, there can be little doubt that this, if not both fub-fpecies of black iron-ftone, are, properly, ores of the former metal.

Subfp. 2. *Black Hematite.*—Colour inclining more to fteel-grey than the preceding fub-fpecies. Occurs maffive and reniform. Internally it is glimmering; luftre femi-metallic. Fracture delicately fibrous, paffing into even. Fragments wedge-fhaped. Occurs in granular diftinct concretions. In other refpects agrees with the preceding.

Before the blow-pipe, both the members of this fpecies melt with borax into a violet-blue coloured glafs. No exact analyfis has yet been made of the black hematite; but its chemical conftitution is in all probability very much fimilar to that of the former fub-fpecies.

Black iron-ftone is found in primitive and fletz mountains, accompanied with brown and fparry iron-ftone and quartz.

It occurs at Naila, in Bareuth; Rafchau, in Saxony; Heffia, the Upper Palatinate, and the Hartz.

Sp. 10. *Clay iron-ftone. Thoneifenftein. Le fer argileux. Ferrum ochraceum argillaceum.*

This widely diftributed, and highly valuable mineral, is divided into feven fub-fpecies; reddle, columnar clay iron-ftone, lenticular clay iron-ftone, jafpery clay iron-ftone, common clay iron-ftone, iron kidney, or kidney-fhaped iron-ore, and pea ore, or pea-fhaped iron-ore.

Subfp. 1. *Reddle.*—Colour light brownifh-red. Occurs only maffive. Principal fracture flaty, glimmering. Crofs fracture earthy, dull. Fragments tabular, fplintery or indeterminate. Streak lighter than the fracture furface, and more fhining. Soils ftrongly, and may be written with. It is foft, and very foft, fectile, eafily frangible; ftrongly adherent to the tongue, meagre to the touch, and moderately heavy. Sp. gr. 3.1391 to 3 931.

It decrepitates and blackens at a red heat, and, in a more elevated temperature, melts into a kind of pumice of a greenifh-grey colour.

It moft generally occurs in the newer clay flate; and is found in Thuringia, Saxony, Silefia, Salzburg, Heffia, and Siberia.

It is fcarcely ufed for any other purpofe than drawing.

Subfp. 2. *Columnar Clay Iron-ftone.*—Colour brownifh-red, paffing fometimes to cherry-red. Occurs maffive, and in pieces which are more or lefs angular. Surface rough and dull. Internally dull, and fracture earthy. It moft ufually occurs in columnar diftinct concretions. Streak blood-red. It is foft, very eafily frangible, brittle, meagre to the touch, adheres flightly to the tongue, and is moderately heavy.

It blackens before the blow-pipe, and imparts an olive-green colour to borax.

It is but rarely met with, and appears to be, in some instances, of pseudo-volcanic origin. Its occurrence with porcelain jasper, and other minerals which are evidently of that class, gives considerable colour to the idea; but there are cases, as the one observed by Reuss in Bohemia, where it appeared in the centre of a mountain of clay-slate, that are equally opposite in their evidence.

It is found in the isle of Arran, at Sobrusan, Hoschnitz, Delau, and near Prohn, in Bohemia; at Dutweiler, in Saarbrücken; and Amberg, in the Upper Palatinate.

It yields too small a proportion of metal, even where the mineral is sufficiently abundant, to be at all worked as an ore of iron.

Subsp. 3. *Lenticular Clay Iron-stone.*—Colour brownish-red, varying to reddish and yellowish-brown, and greyish-black. Occurs massive. Internally it is strongly glimmering, sometimes glistening, and always semi-metallic. Fracture fine earthy, and sometimes slaty. Fragments indeterminate, blunt-edged. Occurs in distinct concretions, which are frequently lenticular, but sometimes granular. The streak varies with the colour of the specimen: generally lighter. It is usually soft, sometimes very soft, and semi-hard. Sectile, inclining to brittle; very easily frangible, and heavy.

Its composition, according to Lampadius, is

Of oxyd of iron	64.
Alumine	23.
Silex	7.5
Water	5.
Loss	.5
	100

The black varieties, which occur only in the canton of Berne, are said to yield 90 *per cent.* of iron. The red ore, which is found very abundantly in Bohemia, affords 60 *per cent.*

It is distributed in transition and fletz mountains, and generally unmixed with other minerals.

Besides the situations already noticed, it is met with in Suabia, the Netherlands, Bavaria, Franconia, and France.

It is smelted as an ore of iron, and the brown varieties of it, which contain from 30 to 35 *per cent.* of metal, are much valued on account of the excellent quality of the metal that is produced from them.

Subsp. 4. *Jaspery Clay Iron-stone.*—Colour brownish-red. Occurs massive. Internal lustre dull, bordering on glimmering. Fracture flat conchoidal; sometimes even. Fragments rhomboidal, also cubic and trapezoidal. Lighter in the streak. Soft, brittle, easily frangible, and heavy.

It has, hitherto, been only met with in a bed which belongs to the secondary or fletz formation, between Vienna and Hungary.

Subsp. 5. *Common Clay Iron-stone.*—Colour light yellowish-grey, inclining to ash-grey, and passing into blueish and steel-grey, yellowish, reddish, and clove-brown, brick-red, and brownish-red. These colours, particularly the lighter ones, undergo a change on exposure to the air, generally becoming darker. Occurs massive, and in a variety of extraneous forms, especially of shells and vegetables. Internally it is dull. Fracture earthy, sometimes conchoidal and slaty. Fragments indeterminate, blunt-edged; soft; rather brittle; adheres a little to the tongue; is more or less easily frangible; meagre to the touch, and heavy. Sp. gr. from 2.936 to 3.471.

Exposed alone before the blow-pipe it blackens, but does not melt. With borax it enters into a sort of ebullition, and produces a glass of a blackish olive-green colour. It varies considerably in the proportion of its ingredients. Some specimens of the mineral yield as much as 40 *per cent.* of oxyd of iron, whilst others do not afford more than 20 *per cent.*, and many even less than that. The following, which will contribute to shew this, are the results of some analyses by Richter and Lampadius.

Oxyd of iron	20.1	33.9	39.	42.5
Oxyd of manganese	1.	1.1		3.
Silex	19.9	23.9	5.	13.8
Alumine	30.2	13.	40.	13.6
Magnesia			6.	
Carbonic acid	28.8	28.1		27.1
Water			9.	
Sulphur			1.	
	100	100	100	100

This subspecies is a very abundant one, and occurs in beds in the secondary or fletz formation.

It is found very plentifully in different parts of England and Scotland; and is also met with in Westphalia, Bohemia, Silesia, the Upper Palatinate, Poland, Russia, Siberia, Italy, and Norway.

Subsp. 6. *Reniform iron ore.*—Colour yellowish-brown, varying in intensity in the same specimen. The centre is the lightest, and not unfrequently includes a small kernel of an ochre-yellow tint. Occurs in masses from the size of a walnut to that of a man's head, which are most commonly imbedded in clay or shale. Fractured towards the surface, even; in the interior fine earthy. Fragments indeterminate, rather sharp-edged. Internal lustre dull; externally glimmering, semi-metallic. It is composed of concentric, lamellar, distinct concretions, inclosing a nodule, which is often loose. Surface rough; external layers soft; those of the centre very soft; brittle; easily frangible; adheres to the tongue; is meagre to the touch, and moderately heavy. Sp. gr. 2.574.

It does not melt before the blow-pipe, when heated alone; but enters into fusion with borax, and communicates to it a dirty yellow colour.

Occurs in the newest fletz rocks, imbedded in the argillaceous strata that are incumbent on coal.

It is found abundantly in Derbyshire, and some of the neighbouring counties; in Scotland, Norway, Denmark, Bohemia, Silesia, Transylvania, France, and Siberia.

The greatest proportion of the iron manufactured in the midland districts of England, as well as in many parts of Scotland, is obtained from the two foregoing subspecies. The metal which they afford, too, is, generally speaking, of the best quality. This is principally referable to the liberal supply of earthy matter in their composition; for, without a sufficient production of scoria, or cinder, in the blast-furnace, the highly carbonized, and consequently most valuable, varieties of iron cannot be formed. These subjects will be more fully discussed in a succeeding section of the article.

Subsp. 7. *Pisiform iron-stone.*—Colour yellowish-brown, of different shades, passing sometimes to blackish-brown. This is its internal appearance. Externally, it varies according to the nature of the stratum in which it is imbedded, being reddish, yellowish, and liver-brown, and even yellowish-grey. Occurs in small spherical grains. Centre of the grain dull; lustre increasing towards the surface to glistening. Internal fracture fine earthy; externally, even. Fragments indeterminate, somewhat sharp-

edged. Occurs in concentric, lamellar, diſtinct concretions. Streak yellowiſh-brown. It is ſemi-hard, paſſing to ſoft. Not very brittle; eaſily frangible. Sp. gr. 5.207.

It exhibits, before the blow-pipe, the ſame appearances as the laſt ſubſpecies. Subjoined are the reſults of two analyſes of it; the former by Vauquelin, the latter by Mallinghof:

Iron	30	
Oxygen	18	
Alumine	31	
Silex	15	
Water	6	
	100	100

This mineral is ſuppoſed by Werner to occur in the ſecond fletz lime-ſtone, and in clay-beds.

It is found in France, Switzerland, Franconia, Heſſia, Suabia, the duchy of Wirtemberg, and Dalmatia. In the latter country, it is ſaid to be uſed by the inhabitants inſtead of ſhot.

The greater part of the French iron is extracted from this ſubſpecies. It yields, in the large way, from 30 to 40 *per cent.* of metal.

Sp. 11. *Bog iron ore. Raſeneiſenſtein. Le fer limoneux. Ferrum ochraceum ceſpititium.*

Werner divides this into three ſubſpecies; moraſs ore, ſwamp ore, and meadow ore.

Subſp. 1. *Moraſs ore.*—Colour yellowiſh-brown. It is ſometimes friable, and ſometimes approaching to coherent. When the latter, it occurs maſſive, corroded, and in grains. The former varieties conſiſt of duſty particles. Luſtre dull. Fracture earthy. Fragments indeterminate, blunt-edged. Soils conſiderably. Is meagre to the touch, and light.

Subſp. 2. *Swamp ore.*—Colour dark yellowiſh-brown, ſometimes paſſing to yellowiſh-grey. Occurs corroded, veſicular, and amorphous. Luſtre dull, ſometimes ſlightly glimmering. Fracture earthy, paſſing to fine-grained, uneven. Fragments indeterminate, blunt-edged. Streak light yellowiſh-brown. Very ſoft; ſectile. Eaſily frangible, and moderately heavy. Sp. gr. 2.944.

Subſp. 3. *Meadow ore.*—Colour, when freſh broken, blackiſh-brown, paſſing ſometimes to yellowiſh-brown, and browniſh-black. Occurs maſſive, in grains, tuberoſe, perforated, and amorphous. Externally it is rough and dull. In the interior it varies from ſhining to glimmering; luſtre reſinous. Fracture conchoidal, paſſing ſometimes to ſmall-grained, uneven, and earthy. The conchoidal varieties have the brighteſt luſtre. Fragments indeterminate, blunt-edged. Streak light yellowiſh-brown. Soft; brittle. Very eaſily frangible, and heavy.

Bog-iron ore in general blackens before the blow-pipe, without melting. It enters into ebullition with borax, and produces a glaſs of a dirtyiſh yellow colour. The only member of the ſpecies that appears to have been ſubjected to analyſis is the meadow ore: and it is conſtituted, according to the information of M. D'Aubuiſſon, of

Peroxyd of iron	61	
Peroxyd of mangaueſe	7	
Silex	6	
Alumine	2	
Volatile matter	19	
Phoſphoric acid	2.5	
Lime, ſulphur, and loſs	2.5	
	100	Annales de Chimie, t. 75.

The volatile matter, which ſo conſtantly forms a part of the reſults quoted from this chemiſt, almoſt excluſively conſiſts of water; and it was with a view, indeed, of aſcertaining the proportion of this ingredient, that his analytical labours were principally commenced. He ſuppoſes it to be an eſſential conſtituent of the different minerals he has examined, and propoſes to arrange them under the claſs of *hydrats*.

The preſent ſpecies is ſmelted in ſome of the countries that afford it, and yields, in the large way, from 30 to 35 *per cent.* of metal.

It occurs in the neweſt formations, and is conceived to be continually depoſited in marſhy places, from the evaporation of the water that has held it in ſolution. The preceding ſubſpecies are products of this proceſs at different ſtages; and the order in which they are arranged is indicative of the date of their formation.

It is found in different parts of the Highlands of Scotland, the Hebrides, Orknies, and the Shetland iſlands. Poland and Pruſſia contain conſiderable quantities of it; as alſo do Brandenburg, Courland, Livonia, and Lithuania. Its occurrence is more frequent in the northern than in the ſouthern countries of Europe.

Sp. 12. *Blue iron earth. Blaue eiſenerde. Le fer terreux bleu. Ferrum ochraceum cæruleum.*

Before it has been expoſed to the air, its colour is greyiſh-white, but afterwards becomes indigo-blue of different ſhades, and ſometimes ſmalt-blue. Occurs maſſive, and diſſeminated; and is compoſed of dull, duſty particles, which are friable and cohering. Soils ſlightly. Feels meagre, and is moderately heavy.

Before the blow-pipe, it becomes of a reddiſh-brown, and afterwards melts into a brilliant black globule, which tinges borax of a deep yellow. It is readily ſoluble in acids. Bergmann had ſuppoſed it to be a native *Pruſſian-blue;* and it has received a place in many mineralogical ſyſtems, under that name, from the ſame belief: but an analytical examination of it by Klaproth ſeems to prove it to be a compound of phoſphat of iron and alumine.

It occurs in neſts in clay-beds, amongſt bog-iron ore, and incruſting turf and peat.

It is found, under the latter circumſtances, in the Shetland iſlands; it alſo appears in Iceland, Saxony, Sileſia, Swabia, Bavaria, Poland, Siberia, Ruſſia, and Sweden.

Sp. 13. *Pitchy iron ore. Eiſenpecherez. Fer phoſphaté.*

Colour pitch-black, paſſing ſometimes into blackiſh-brown, and even deep reddiſh-brown. Occurs maſſive. Surface earthy, and dull. Internally it is gliſtening; luſtre reſinous. Fracture foliated, conchoidal, and ſometimes fine-grained, uneven. Fragments indeterminate, tolerably ſharp-edged. Opaque; ſemi-hard; brittle. Not very eaſily frangible, and moderately heavy. Sp. gr. 3.956.

It melts eaſily before the blow-pipe, and forms a black enamel. According to Vauquelin, it conſiſts of

Phoſphoric acid	27
Oxyd of iron	31
Oxyd of mangaueſe	42
	100

Is found near Limoges, in France.

Sp. 14. *Green iron earth. Grüne eiſenerde. Le fer terreux vert. Ferrum ochraceum viride.*

This is divided into two ſubſpecies; friable green iron earth, and coherent green iron earth.

Subſp. 1. *Friable green iron earth.*—Colour ſiſkin-green. Occurs maſſive, and diſſeminated; and conſiſts of particles

which are without lustre. Fragments indeterminate; soils; is soft, and very soft. Sometimes friable. Meagre to the touch. Easily frangible, and moderately heavy.

Subsp. 2. *Coherent green iron earth.*—Colour rather darker than the last subspecies. Occurs massive, and corroded. Internally dull. Fracture fine earthy, passing into even, and sometimes into splintery. Fragments indeterminate; soft. Rather brittle, and inclining to heavy.

Before the blow-pipe, it becomes first red, and then of a dark brown; but does not melt. It tinges borax of a yellow colour, inclining to olive-green. No exact analysis has been made of this species; but it is supposed by Werner to have iron and phosphoric acid for its principal ingredients.

It is a rare mineral, and has hitherto been only found at Braunsdorf and Schneiberg, in Saxony, where it occurs in veins: in the former place, accompanied with quartz and pyrites; and in the latter, with quartz and native bismuth.

Sp. 15. *Cube-ore. Wurfelerz. Fer arseniate.*

Colour olive-green, of different degrees of intensity. Occurs massive, disseminated, and crystallized in small and very small cubes, which are sometimes flattened and truncated at the angles. Planes of the crystals smooth and splendent. Internally it is glistening, and its lustre between pearly and adamantine. Fracture imperfect foliated. Fragments indeterminate. Occurs in granular distinct concretions. It is translucent; soft; brittle, and gives a streak of a straw-yellow colour. Sp. gr. 3.000. It appears sometimes in the form of a reddish-yellow powder, which is thinly distributed over the surface.

Before the blow-pipe it swells up, and emits an arsenical odour; melting afterwards into a grey metallic globule, slightly tinged with yellow. From the analysis of Chenevix, it appears to be composed of

Arsenic acid	31.
Oxyd of iron	45.5
Oxyd of copper	9.
Silex	4.
Water of crystallization	10.5
	100

It occurs in veins, accompanied with some ores of copper, quartz, mica, and feldspar.

The only places that have, hitherto, afforded it, are the mines of Carrarach and Muttrell, in Cornwall.

Until the account published of this mineral by the count de Bournon, and Mr. Chenevix, in the Philosophical Transactions for 1801, it was mistaken for an arseniat of copper.

§ 2. *Assay and Analysis.*

Since the metal contained in every ore is of so much greater specific gravity than any other of its accompanying ingredients, it will be easy to form a tolerable idea of the value of an iron-ore by the weight of a given bulk.

Previously to working any iron-ore it should be very minutely analysed, both in the humid and dry way. By the humid process we shall ascertain the exact proportions of its constituents, without which it would be a mere work of chance to attempt to extract the iron in the metallic form.

When we are acquainted with the nature of the earthy matter in combination with the ore, we know with the greatest certainty what substances we ought to add in the crucible, for the purpose of eliminating the metal. All such substances are called fluxes, merely because they form fusible compounds with the earthy matter of the mineral. It is to this treatment of a small quantity of the ore that we give the name of assaying.

The process by which the component parts are ascertained, consists in subjecting a small quantity of the ore in fine powder to the action of an acid, and sometimes to an alkali. By this means the whole is dissolved, and the different materials of which it is composed are separately precipitated by different chemical re-agents. The process, however, varies considerably with the nature of the ore to be examined.

Iron ores, as subjects of analysis, are divided into three heads; namely, sulphurets, oxyds, and salts.

The first are distinguished by their general bronze colour, but more particularly by the suffocating smell of sulphureous acid gas, which they afford by being heated to redness in the open air. The second consist of iron united with oxygen, and are by far the most common of all. Nearly the whole of the iron-ores in use are of this kind, containing also different proportions of earthy matter in their composition.

The third division comprehends such as consist of the oxyd of iron combined with some acid, and hence are called salts. The principal varieties of these are the phosphats, sulphats, arseniats, and carbonats.

The apparatus employed in the humid analysis will be a lamp fitted up with different-sized sliding-bearers, a silver crucible, and small portable furnace, with a sand-bath, and one of water, for drying precipitates; capsules of glass and porcelain; precipitating glasses, funnels, and filtering paper. For reducing the ore to powder, a mortar of hardened steel will be first necessary, and afterwards one of agate, to grind it very fine. Accurate weights and scales will be highly requisite, with cups of silver or platina.

The re-agents wanted will be sulphuric, muriatic, and nitric acids. Pure potash, soda, and borax, in the solid form. Solutions of the same, and also the pure aqua ammonia. The fully saturated carbonats of all the alkalis, and the subcarbonats of the same. The triple prussiat of potash and iron; and, when merely used as a test, prussiat of lime will answer. The analyst should, also, have in his possession powders or solutions of all the separate substances of which the mineral is supposed to consist, for the purpose of comparing real results with those obtained in his experiments.

If the ore to be analysed be a pure sulphuret, 100 grains, or any other given weight, may be reduced to powder, observing to weigh it after the operation, to see if any of the mortar has been abraded, which, when the ore is very hard, is to be expected; and the increased weight must in that case be noted down.

Let this powder be boiled with nitric acid in a long narrow-beaked glass vessel, which should be very thin at the bottom, to avoid cracking. By this method the sulphur of the ore will be converted into sulphuric acid; part of the nitric acid will be decomposed, and most of the remainder fly off, so that the resulting fluid will principally consist of the iron dissolved in sulphuric acid.

To this solution add the muriat of barytes, till a precipitation ceases to take place. When the precipitate has subsided, and the fluid is become perfectly clear, gently pour off the liquor, which is a solution now of iron in the muriatic acid. Let the precipitate, consisting of sulphat of barytes, be repeatedly washed with hot distilled water, till the liquid gives no precipitate with nitrat of silver, and afterwards add the washings to the fluid first poured off. After this white powder has been dried on the steam-bath, which is an apparatus constructed for this particular use, let it be weighed, and for every 100 grains of the substance allow 21.3 of sulphur. To the liquid parts which contain the oxyd of iron,

add a clear solution of the sub-carbonat of potash. Let it boil for a little time, and the oxyd of iron will subside. Wash it and dry it as above, afterwards weighing the product. The quantity of oxygen in the oxyd of iron thus obtained, may be known by the quantity of iron obtained from it in the process of assaying, which we shall afterwards give. If the ore consist of oxygen and iron only, it may, without any previous treatment, be referred to the dry process. When, however, earthy matter is combined with it, the humid analysis should be resorted to, which requires a different mode of proceeding to that already given.

Let 100 grains of the ore be reduced to a fine powder, as above directed, observing to weigh it afterwards, for the purpose of ascertaining whether any of the materials of the mortar be mixed with it. The matter so added, if it be acquired from the agate mortar, may be deemed pure silex.

To this powder add 300 grains of dry potash, in a silver crucible, capable of holding about six or seven ounces. Pour to the mixture a very little water, just sufficient to moisten the whole. Apply a gentle heat in the first instance, to prevent the mass from swelling too much, and gradually increase the temperature till the crucible is red-hot. The mass will now be in a state of fusion more or less perfect, according to the quantity of silex contained in the ore. If, from a great proportion of alumine being present, the fusion should be very imperfect, more potash must be added, and the heat continued and raised as high as the crucible will bear. When the crucible, with its contents, are sufficiently cooled, let both together be put into a capsule of porcelain, and nearly filled with distilled water. The whole should then be set upon a sand-bath, and boiled for some time, taking care to stir it very frequently. This will detach the matter adhering to the crucible, and if any silex remain unacted upon, it will be dissolved by the potash.

Let the whole be now saturated with muriatic acid, and even added a little in excess; and then gently boiled till all the liquid is evaporated. During this, the mixture must be constantly stirred; and particularly at the time the mass is becoming dry.

To this residuum let a large quantity of distilled water be poured. All the substances soluble in the acid will be now taken up. If it contain silex that will be left at the bottom. Let the whole be decanted into a narrow tall glass vessel, to suffer the silex to subside. Carefully pour off the clear liquor, and then add fresh hot distilled water, and continue to do so till the fluid does not cause a precipitate with nitrat of silver; observing to save all the washings which are acted upon by that test. The remaining water may now be evaporated from the silex, and the powder, being heated red-hot in a crucible of silver or platina, should be then weighed. If it be pure, it will be of a delicate white colour, not adhering to the fingers, as is the case with some of the other earths.

The solution containing the remaining substances should be evaporated to as small a quantity as possible, so that the fluid remain liquid and clear. To this let a saturated solution of the subcarbonat of potash be added, and afterwards boiled a few minutes. By this means, the whole of the ingredients will be precipitated together, and when all of them have perfectly subsided, decant off the liquor, repeatedly washing it with hot water. The first decanted liquor, with the washings, may be thrown away. Lastly, evaporate the remaining water, till the solid matter is of a pulpy consistence. To this, in a capsule of good porcelain, add a solution of pure potash. The alumine will be thus dissolved, while all the other substances will remain untouched. Let this fluid be poured off, and fresh water mingled with it, to take away all the alumine. Then, to the mixture containing the alumine, add not only as much acid as will saturate the potash, but also a quantity sufficient to dissolve the alumine, when the liquid will be quite clear. Finally, to this pour in carbonat of ammonia, till no more precipitate falls down. The precipitate, when washed and dried as above directed, and heated to redness in a silver crucible, may be considered as pure alumine.

The residuum from which the alumine was last taken is now to be dissolved in sulphuric acid, diluted with a large quantity of water, the acid being slightly in excess. This solution may contain magnesia, iron, and probably manganese. If lime were present, it will be left insoluble at the bottom of the vessel, in the state of sulphat of lime. The small portion of this substance dissolved by the fluid, may be precipitated by the addition of alcohol. The powder, when collected and dried at a dull red heat, must be weighed; allowing for every 100 parts 42 of pure lime. The solution from which the lime was separated, must next be saturated with a solution of the neutral carbonat of potash. In a few minutes the iron will be precipitated in the state of oxyd, while the magnesia and manganese will be dissolved by the carbonic acid. The iron must be separated, dried, and weighed. If with the solution containing the magnesia and manganese a solution of hydrosulphuret of potash be mingled, the latter will be precipitated in the form of a sulphuret; and this being washed and heated till the sulphur is driven off, the oxyd of manganese will be left in sufficient purity.

The magnesia still held in solution may be precipitated by adding a sufficient quantity of pure potash. The product must be heated to redness, and weighed. The weights of the different substances being added together, will, if great care has been used, be within one or two *per cent.* of the quantity originally submitted to experiment. If the deficiency be considerable, some mistake must have been made, and it will be necessary to repeat the analysis.

In the examination of salts of iron, nothing more is requisite than to disengage the acid with which the iron is combined. The arseniat of iron, for example, must be boiled with potash, which will separate the arsenic acid, and leave the oxyd of iron but very little acted upon. The arsenic acid may be afterwards precipitated by nitrat of lead; allowing for every 100 parts of the arseniat of lead, when dried, 33 parts of arsenic acid.

If the ore be a pure carbonat, to 100 grains in powder, add an equal quantity of sulphuric acid, in a glass vessel which can be placed over a lamp. Heat the mixture for some time, stirring it with a glass rod. The carbonic acid will be thus expelled, and its quantity will be indicated by the loss of weight sustained. Care should, of course, be taken that the heat be not too great, otherwise the evaporation of fluid matter may create error in the experiment. The iron may be afterwards treated as in the analysis of the earthy ores, and its quantity ascertained, by the methods there described. Having learned the exact proportions of the ingredients united in the ore, we may, with some degree of certainty, proceed to the assay by the crucible and fluxes. If the ore consist of oxyd of iron simply, nothing more is necessary than to introduce it into a crucible with about half its weight of charcoal powder, and any substance susceptible of vitrification, so as to keep off the air. This may be either pounded glass, or equal parts of lime and clay. But perhaps the best substance that can be employed, is the most fusible part of the blast furnace cinder, which is the least coloured with oxyd of iron. This may be employed in quantity

amounting to about half the weight of the mineral to be aſſayed.

The earthy iron ore muſt be treated according to the reſult of the humid analyſis; ſuch earth being added as a flux, as will make the moſt fuſible compound with that found by analyſis to be preſent. The carbonaceous matter may be from [illegible] to $\frac{1}{2}$ the weight of oxyd of iron.

The furnace beſt calculated for theſe experiments is called an aſſay furnace, and is capable of producing a great heat. See FURNACE.

The crucibles ſhould be very ſmall, not capable of holding more than three fluid ounces; and they ſhould be provided with covers turned to them in a lathe before they are burned. The aſſay may be deemed finiſhed when the whole is in a ſtate of fuſion, and the metallic button ſeparated, which, being weighed, will give the *per centage* of iron in the ore.

§ 3. *Reduction of Ores, and Manufacture of Pig-iron.*

Although iron in its pure ſtate is almoſt an infuſible ſubſtance, it is capable of aſſuming the liquid form, by being combined with other matter. With ſulphur it forms a fuſible maſs, of which we ſhall treat hereafter. It is alſo rendered fuſible at a temperature ſomething higher than that required to melt copper, by being combined with about $\frac{1}{15}$th of its weight of carbon. It is to this compound in different proportions that the name of pig-iron is given, and it is ſo denominated, becauſe it is caſt into maſſes of a ſemi-cylindrical ſhape, called *pigs*.

The fuſibility of this compound of iron and carbon, enables us to extract the metal from the ore to the greateſt advantage. It is now common, particularly in our own country, to obtain the iron in this form, previous to making it into bar, or malleable iron. Formerly caſt metal was not much in uſe, except for the manufacture of bar-iron and ſteel; while in the preſent day, a much greater proportion of it is conſumed in that ſtate than in any other; and the majority of our furnaces, too, are ſolely employed for this branch of manufacture.

The proceſs by which pig-iron is obtained from the different iron ores is called *ſmelting*; and the furnaces employed for the purpoſe are called *ſmelting*, or *blaſt furnaces*. See BLAST *furnace*, and BLOWING.

The ores of iron require different treatment in the ſmelting proceſs, according to the quantity of heterogeneous matter with which the metal is combined.

In all the ores the iron is in the ſtate of oxyd, and would at leaſt require a ſtrong heat in contact with combuſtible matter for their reduction. In moſt, the oxyd of iron is combined with a conſiderable proportion of earthy matter, and they are then denominated *iron-ſtones*. Theſe may be generally divided into two claſſes; the one called argillaceous, from abounding with exceſs of alumine, or clay; and the other calcareous, from lime being their principal earthy conſtituent. The former of theſe iron-ſtones is by far the moſt abundant in this country.

But, beſides the earthy matter and oxygen in this claſs of metallic minerals, many of them contain ſulphur, which is doubtleſs combined with the iron in the ſtate of pyrites. Arſenic and mangancſe are alſo ſometimes united with them. Of the above, the arſenic and ſulphur are extricated, previouſly to ſmelting, by the proceſs called *roaſting*. For this purpoſe, the ſtone is ſtratified with refuſe pit coal, and burnt in large heaps in the open air. The heat is ſufficient to diſſipate the greateſt part of the above volatile materials, leaving behind the earth and oxyd of iron; and alſo the manganeſe, when the ore abounds with that metal.

In the proceſs of ſmelting, two things are abſolutely eſſential to the ſeparation of the iron. Firſt, the metal itſelf muſt be rendered fluid, which will then, by its great ſpecific gravity, deſcend to the loweſt parts of the furnace, and ſome other compound muſt, at the ſame time, be eliminated in a liquid form, ſo as to float upon its ſurface, and defend it from the influence of the blaſt. If the ore conſiſted of iron and oxygen alone, the carbon of the coke would combine with the oxygen; and an exceſs of carbon would alſo unite with the iron to render it liquid at that temperature; but here would be a deficiency of the fluid vitreous matter neceſſary to the defence of the iron from the oxygen of the blaſt. Hence it will be neceſſary to employ ſome ſubſtance with ſuch iron-ore, which ſhall be capable of forming a liquid ſcoria, or cinder, for the preſervation of the carburetted iron, when once obtained. So far as obſervation has dictated, it would ſeem that the cinder cannot be too perfectly fluid. The principles on which the fuſibility of the cinder depends, are not ſimply confined to the materials uſed in the ſmelting of iron, but refer to all compound fuſible matter with which we are acquainted. It may be obſerved, in general, and, indeed, almoſt without exception, that the fuſibility of an alloy of two metals is fuſible at a temperature much leſs than the arithmetical mean between the fuſing points of the metals themſelves. For inſtance, an alloy of lead and tin is more fuſible than either of the metals compoſing it, and a ſimilar mixture of copper and ſilver may be uſed as a ſolder for either ſilver or copper ſeparately. This property is not leſs conſpicuous in the earths. None of them in their *pure* ſtate can be fuſed in our hotteſt furnaces; nor ſcarcely with a ſtream of oxygen gas; although certain proportions of them are, together, fuſible at the heat of a moderate air-furnace. Lime and clay, when ſeparately taken, may be conſidered as incapable of fuſion at any degree of heat, yet produced in furnaces; and ſtill, in certain proportions, they are too fuſible to be made into even bricks or crucibles. It will appear, from theſe facts, that the iron-maſter cannot pay too much attention to the ſubject of the relative fuſibility of the earths in different proportions. Moſt of the iron-ores of this country are argillaceous; that is, conſiſt, beſides oxyd of iron, of a ſmall quantity of ſilex or flint, and a large proportion of clay. Limeſtone has always been employed for ſuch ores, and, by combining with the clay and flint, as well as with a ſmall portion of the oxyd of iron, forms a ſcoria or cinder, eaſily capable of fuſion. Since, however, the proportions of theſe earths in the ore cannot be uniform, the quantity of limeſtone to be added ought to vary according to circumſtances. We may hence infer, that if the fuſibility of the cinder depends upon the particular proportions of the earths preſent, the iron-maker ought to poſſeſs a very perfect knowledge of the relative fuſibility of different combinations of theſe bodies, and being at the ſame time aware of the component parts of the ore to be reduced, he will not be at a loſs what ſhould be added in the furnace, for the purpoſe of producing the moſt fuſible cinder. But it will be proper here to obſerve, that the earths preſent, however accurate may be their proportions, will not of themſelves form a cinder of ſufficient fuſibility, without the united aid of the oxyd of iron. This fact will be very familiar to thoſe who have had experience in the uſe of fire-bricks. Clays which are free from that ingredient do not burn of a red colour; and hence the white appearance of fire-bricks is a tolerable teſt of their goodneſs. But thoſe, on the contrary, which exhibit a redneſs on being fired, are eaſily fuſed, and unfit, conſequently, to be uſed in thoſe ſituations which are expoſed to great heat. The proportions of lime, clay, and oxyd of iron, neceſſary to conſtitute the moſt fuſible com-

pound, has not, as we have yet heard, been directly ascertained by experiment. An inquiry, undertaken with this view, would, however, be of great importance to the iron-master. It might be effected in two ways; first, by mixing different proportions of the materials employed; and, secondly, by a direct analysis of the most fusible part of the blast-furnace cinder, and that with which the best and most carbonated iron has been produced. The cinder which fuses at the lowest temperature will be best known by its fracture after cooling. It may, in general, be deemed good in proportion to its earthiness when solid, and particularly should the outer crust appear glassy and transparent. A reason may be given for this appearance, by reference to some facts announced by sir James Hall and Dr. Hope, in accounting for the opacity of the whin-stone. They found that when common flint-glass, which is more fusible than the blast-furnace cinder, was allowed to cool slowly, the mass became opaque, and put on a stony appearance. They hence concluded, that the whin-stone might have been transparent, and have possessed a glassy fracture, had it been cooled rapidly. The inference to be drawn from this will be obvious; for the more fusible the cinder, the longer it is in cooling, and consequently the more opaque. What strengthens this idea, too, is, that the exterior of a mass of cinder is more transparent, almost constantly, than the interior; and the centre of that in particular, under which the best iron is made, having a stony fracture, with a thin vitreous shell surrounding its outside. In beginning to work any new ore of iron, the first step is to analyse it, both in the dry and humid way. By the first, we get the *per centage* of iron in the one; and by the second, we become acquainted with the quality and proportions of its earthy matter. The next step is to analyse the coal to be employed, for the purpose of ascertaining the quantity of carbon it contains, and also the nature and proportions of its earthy residua. These facts being clearly made out, there will be nothing necessary but to add to these materials a proper mixture of such substance as will make the most fusible cinder. If the ore be argillaceous, or, in other words, if clay predominate, lime is to be the material employed. Indeed, ores of this description are so very common, that lime has been thought the only substance to be used, under all circumstances, for the purposes of a flux; and so completely ignorant have the iron-makers been of the philosophy of the process, that it has even been attempted to be added when the ore has already abounded with calcareous ingredients.

Keeping in view the principles we have just laid down, the management of the calcareous ore will be equally easy with the mode of working the argillaceous; since, in such case, we have only to employ clay for the flux instead of lime. But the best method would, perhaps, be, if the component parts of an argillaceous and a calcareous ore were sufficiently well known, to mix the two together in proper proportions.

Whatever may be the substance employed, whether it be limestone for an argillaceous ore, or clay for a calcareous ore, it should be very minutely analysed, as those substances are scarcely ever found in a state of purity. The lime should, if possible, be the shell limestone. At all events, the magnesian stratum should be avoided, since that substance tends much to lessen the fusibility of earthy compounds. Some substances, to which we give the name of clay, frequently consist of a large proportion of some other earth.

Another thing to be attended to, also, is the state of oxydation in which we find the iron-ore.

If it be highly oxydated, more of the carbonaceous matter will be required for its reduction, and in all probability a longer time; but, besides this, a greater quantity of the oxyd of iron will combine with the earthy matter, which, although it may contribute to the fusibility of the cinder, a large portion of the iron will be lost. On the contrary, when the iron is in a low state of oxydation, the whole of the iron may be apt to combine with the carbon, and the earthy matter may not get a sufficient quantity of the oxyd to render it, in a proper degree, fusible. In such case, it would be necessary to add some oxyd of iron, which might more easily vitrify and enter into the composition of the cinder.

The coal employed in the smelting of iron, for the purpose of being coked, is commonly laid in heaps in the open air, and afterwards set on fire. When the combustion has gone on to a certain degree, the fire is checked by covering it with dust and preventing all possible access of air. For farther particulars, see Coke.

It is essential that the coke should be harder than it can generally be made in the open air without considerable waste; and we recommend, therefore, the method employed in making the cokes for melting steel. The coal, which is very soft, is piled up in ovens of the shape of an erect frustum of a cone. The air is let in at an aperture near to the bottom, which is contracted in size as the combustion becomes rapid, and ultimately closed. The whole mass will at this time have acquired such a degree of heat, as not only to drive off all the volatile matter, but to render the coke extremely hard. There is a considerable saving in this mode of coking, and the coke is not only more compact, but better adapted for the generality of ores of iron.

In smelting the argillaceous ore, the proportions of the roasted ore, and the limestone, are governed entirely by the coke employed. The latter is always a fixed quantity, and the ore and limestone are varied according to the quality of the iron to be made and the working order of the furnace. In proportion as more or less of lime and ore are added to the standard quantity of coke, the furnace is said to carry a greater or less burthen.

It would be useless to give any precise proportions of the ore and limestone to a given quantity of the fuel, since they are found to vary with the nature of the coal in use; and, what is not a little remarkable, the proportions will frequently vary in two furnaces working with the same coal, and even in the same furnace at different times.

The burthen of the furnace will also vary with the quality of iron to be made, that is, as it is required to contain more or less carbon. In making the dark-grey iron called N 1, and which contains the greatest proportion of carbon, the burthen must be less than that required to make the less carburetted iron, commonly called white iron, or *forge-pig*.

To give a general idea of the proportions of the materials, we shall present in detail, the quantities used at a blast-furnace, making in general good melting iron, which is of an intermediate quality between N 1 and the *forge-pig*. The ore is argillaceous, containing about 27 *per cent.* of iron; the coal rather soft, but having a good proportion of carbonaceous matter; and the limestone good, being of the shelly kind before spoken of. The furnace is about 45 feet high, and $12\frac{1}{2}$ feet diameter in the widest part. It works with a bright *tuyere*, and receives from the blast about 2500 cubic feet of air in a minute, through a circular aperture of $2\frac{1}{4}$ inches in diameter.

The average charges of coke per *shift*, as it is termed, or in the space of 12 hours, are 50 (each $2\frac{1}{4}$ *cwt.*), or nearly seven tons. The calcined ore for good melting iron is about the same quantity; and for forge-pig, or the least carburetted

variety, six of coke to seven of ore. The limestone unburnt, under the same circumstances, is to coke as four to eleven; and, for melting metal, retains a similar ratio. With the above charge per day, that is, for 12 hours, this furnace makes on the average about 40 tons of melting iron per week.

Some furnaces carry so little burthen as not to yield more than 13 or 14 tons weekly; whilst others, particularly in South Wales, produce, with the same sized furnace, as much as 60 and even 70 tons in an equal time. The burthen of these furnaces is very great, the ore to the coke being in some cases as 13 to 7; and the quality of the iron is uniformly inferior. Since the cavity in the furnace is constantly kept full of the above materials, it may easily be conceived that the whole must be in many intermediate stages, from the fully melted iron to the unchanged ore. At the point where the greatest heat is produced, which will be a little above the level of the blast, every thing capable of fusion will be assuming the liquid form. We cannot, however, for a moment suppose, that the iron at this point is in a state of oxyd, since it would of necessity be all vitrified, and enter into the composition of the cinder. If the iron, even in its carburetted form, were to remain long at so great a temperature, and within the influence of so much oxygen, it would first lose all its carbon, and ultimately pass into the state of vitreous oxyd. As, however, the oxygen of the blast rises in the furnace, it comes in contact with the carbon of the coke, and is very soon converted into carbonic acid gas. That point in the furnace, therefore, where the whole of the oxygen has entered into combination with carbon, may be denominated the commencement of cementation, or the point where the oxyd of iron is first deprived of oxygen, and ultimately saturated or *cemented*, as it is termed, with carbon. From this point to the top of the furnace the process of cementation is going on with different degrees of rapidity, proportionate to the temperature. It is found by experiment, that if a piece of iron-ore, particularly any of the oxyds that contain but little earthy matter, be exposed in a close vessel in contact with carbon, it will first lose the whole of its oxygen, and afterwards become so saturated with carbon, as to be capable of fusing into the best pig-iron. Hence it appears that the reduction of the ore, so far as relates to the deoxydation and carbonization of the iron, may take place at a temperature below fusion, and without the mass of ore changing its form. The ore exposed to the carbonaceous matter in the cementing part of the furnace, must as completely undergo a similar change as if it were in the closest vessel; for the oxygen is excluded by the presence of carbonic acid gas. When the carbonized, but yet solid, iron, in the form of the ore, falls below the cementing point, or perhaps short of that, it begins to fuse. The earthy matter of the ore, being in contact with lime, begins also to assume the liquid form; and whilst the melted metal is exposed to the oxygen of the blast, a small portion of oxyd of iron is produced, which will enter into the composition of the cinder, and thus tend to increase its fusibility. The liquid iron now drops into the chamber of the furnace called the *hearth;* and the liquid cinder, being of less specific gravity, floats upon its surface, completely defending it from the oxygen of the blast. Hence we see that the column of the blast-furnace may be divided into three portions; the upper portion, or cementing part; the middle, or melting part; and the chamber, or hearth, where the metal is preserved till it is in sufficient quantity to be run out into pigs. The cementing portion is by far the most extensive, and will vary in its extent with the strength of the blast.

Since the combustion must be in proportion to the quantity of oxygen consumed in a given time, the heat of the furnace will depend upon the quantity and velocity of the air blown into it to a certain extent. If the blast should have too great a velocity, the oxygen would pass through a greater space in the furnace than is desirable before it was disposed of, and the cementing portion would be lessened in consequence. On the contrary, if the velocity were too little, the heat would be confined to the vicinity of the tuyere, and the cementing, as well as the melting processes, would be retarded for want of heat.

When the blast is sufficient to generate the necessary heat for melting the cinder and the metal perfectly, the extent of the cementing portion will depend upon the height of the furnace. This gives us one very satisfactory reason, why a furnace is required to be higher for the use of coke, than when it is heated with charcoal; since the carbon of the latter enters into the composition of the iron with much more facility than that of the former.

According to experiment, it appears that the facility with which carbon enters into combination with iron, in a close vessel, is inversely as its aggregation or cohesion. Hence it is found, that the carbon obtained from animal substances, which is soft and porous, is best calculated to convert iron into a carburet.

It will appear from the last observation, and from what has been said on the nature of coke, that the carbon employed for cementation should be mechanically different from that required to generate the great and permanent heat necessary to the fusion of the materials. The one in the cementing portion should, therefore, if it were practicable, be surrounded with coke of the softest kind, while the materials within the influence of the blast, and occupying the melting portion, should be supplied with such as is harder.

In making the most highly carbonized iron, or what is called N° 1, it sometimes happens that a portion of the iron unites with a great excess of carbon, forming a substance, which, when cold, appears in bright shining scales. It is found to possess most of the properties of plumbago, differing from that substance only in containing less carbon. This carburet is no doubt in the liquid form in the furnace, and, being of much less specific gravity than the iron, floats upon its surface. It is so much more infusible than the metal, that before the iron enters the moulds of the pig-bed it is seen swimming at the top in the scaly form before mentioned.

This substance is called by the workmen *kish;* and whenever it appears, is a certain sign that the furnace is working on the best sort of iron. So surely, indeed, is it the case, that N° 1, or the most highly carburetted metal, has received the epithet of *kishy*, because *kish* is the common attendant on its production.

The most remarkable and anomalous circumstance presented in the smelting of iron, is the difference in quantity and quality of the iron made in winter and in summer, when all other things are equal. It is a fact well ascertained, that in order to make the same quantity and quality of iron in summer as in winter, the furnace will not carry so great a burthen, and, at the same time, the means of generating heat requires to be increased.

Various opinions have been given to explain this curious fact. Some have supposed that the proportion of the oxygen was less in the atmosphere in summer than in winter. Others,

that the excefs of moifture contained in the air in fummer above that in the winter, might explain the phenomenon. Whatever may be the caufe of this difference in the blaft-furnace, the fame may equally be referred to common fires, which, it is well known to every one, are much hotter in winter than in fummer. If the Lavoifierian doctrine of combuftion were true, we fhould not expect that the power of air to generate heat would vary with the temperature, fince the fame caloric which had contributed to dilate the oxygen in fummer, would be given up when the oxygen combined with the carbon. Unfortunately for that doctrine, however, we find that the quantity of heat generated during the combination of oxygen, is directly as the quantity of oxygen, whatever may be its ftate, whether folid, liquid, or aeriform.

It appears from general obfervation, that the difference in the quantity and quality of the iron made in winter and fummer may be, in a great meafure, referred to changes arifing from variation of temperature. The average refult of this atmofpheric influence is different with different blaft-furnaces, and, indeed, with the materials employed; but in general the quantity varies in winter and fummer from $\frac{1}{8}$th to $\frac{1}{4}$th, befides the alteration of quality, which in fome furnaces cannot be prevented by any change in the burthen.

If the whole of this difference depend upon the temperature of the blaft fent into the furnace, we muft expect to find it either in the increafed rarity of the air, or in the prefence of moifture, which exifts more abundantly in the atmofphere in fummer than in winter; or, perhaps, it may be attributable to both thefe circumftances.

Soon after the conftituent parts of water were difcovered, fome iron-mafters attempted to produce combuftion by blowing fteam into the furnace. But, notwithftanding the great proportion of oxygen exifting in aqueous vapour, their expectations were far from being realized, and the fcheme was given up by them under a firm conviction that it never could fucceed.

This experiment, however, ferved to fhew that no more mifchief might be expected from the vapour of water in the atmofphere, than its merely excluding a portion of oxygen. Conceiving it, therefore, to have no other influence in the furnace, we will fubmit fome calculations to the reader, in order to fhew the abfolute difference in the quantity of oxygen fent into the furnace in winter and in fummer, and to afcertain what fhare of the defect may be attributed to this circumftance, or whether the whole may not fafely be referred to it.

We have much to regret that we are not in poffeffion of more experiments as to the temperature of the air fent into the furnace at different times of the year. The mere temperature of the atmofphere is not fufficient for this purpofe, fince the air gives out much heat by compreffion in the blowing cylinder. In a former part of this work (fee BLAST-*furnace*), a table of fome obfervations was given, on which, as far as they go, reliance may confidently be placed. In this table the temperature of the air was ftated when it entered the blowing cylinder, and after it had been compreffed into a vault, from which it paffed into the furnace. If we take the temperature on its entrance into the furnace in winter at 50°, and in fummer at 100°, the difference will be 50°, and the variation in the quantity of oxygen will be inverfely as the increafed volume of the air. It is found that elaftic fluids are augmented in bulk by one degree of Fahrenheit .00208 of the whole. Therefore, the quantity of oxygen at 50° will be to that at 100° as $1 + (100 - 50) \times .00208 : 1$; and the oxygen, confequently, in fummer will be .104, or little more than $\frac{1}{10}$th lefs than in winter.

The defect arifing from the relative quantities of moifture contained in the air in winter and fummer will be very trifling, except where the water-regulator is employed inftead of the air vault or common regulator. (See BLAST-*furnace*.) When the air does not come in contact with any thing moift after entering the blowing cylinder, in order to learn the quantity of water prefent, we have only to afcertain the relative proportions of vapour exifting at the refpective temperatures of the atmofphere in winter and fummer. It appears from a theorem, which we have founded upon Mr. Dalton's ingenious experiments upon evaporation and the force of vapours, that the quantity of water in air at 32°, at which temperature we fuppofe it to enter the furnace in winter, is equal to 2.04 grains in each cubic foot. This, in weight, is $\frac{2.04}{561}$; and in bulk, vapour being to air at 32° as 274 to 561, equal to $\frac{2.04}{274}$ of the whole, or .0075. The fummer air, which we take at 55°, contains 5.32 grains in a cubic foot; a quantity amounting in weight to $\frac{5.32}{524}$, and in bulk to $\frac{5.32}{274}$, or .019 of the whole. The difference .0115 is the deficiency of common air in fummer, arifing from the prefence of aqueous vapour; and makes the total variation in the quantity of oxygen between fummer and winter equal to $.1155 = \frac{23}{200}$, or $\frac{1}{9}$th nearly.

We here confider water as producing injury merely by difplacing a certain proportion of oxygen, and not being prejudicial in itfelf, as is fuppofed by the generality of iron-mafters. The reafon given for its bad effects does not appear intitled to much weight. The opinion commonly entertained is, that the carburetted hydrogen fet at liberty, carries off a greater quantity of heat than the nitrogen of atmofpheric air. An effect which, if even true, is inadequate to explain the appearances. When the air is received into a water-regulator, as is the cafe in many blaft-furnace works, a much larger quantity of moifture may be expected to enter the furnace, than with the ordinary apparatus. In the above calculation, if the air had been received over water, we fhould find that its temperature in the receiving veffel in winter and fummer would be 50° and 100°. The vapour in the former amounts to 4.67 grains in a cubic foot: in the latter, to 18.95 grains in the fame quantity.

Hence, air at 100° will contain lefs oxygen than that at 50°, by .055 of the whole; which is a little more than $\frac{1}{20}$th. This added to the lofs by increafed temperature alone, will be .159, or nearly $\frac{1}{6}$th.

We may from this conclude, that the extra-quantity of moifture admitted by ufing the water-regulator, will at any rate increafe the difference in the amount of oxygen from $\frac{1}{9}$th to $\frac{1}{6}$th, or thereabouts; which, in all probability, will more than counter-balance the good effects arifing from its uniform preffure. There does not appear to be, in the prefent ftate of our knowledge, any means of effectually remedying this evil. Some good might accrue from admitting the exterior air as cold as poffible, and not allowing it to come in contact with water after entering the blowing-cylinder. This may be done to a certain degree, by caufing

the air to ascend from a deep pit, by a pipe communicating with the blowing cylinder. This contrivance, however, should be alaid aside whenever the air of the atmosphere becomes colder than the average temperature of the earth.

With regard to the defect arising from increase of volume of the air in the summer months, the heat caused by the friction of the blowing piston will be found to contribute much to the evil. The air by this means gets an additional elasticity, and if the same quantity of air be thrown into the furnace it must be effected by decreasing the pressure of the blast, or by increasing the aperture of the *nose-pipe*. If the compression of the air could be effected by any means which would avoid the friction of machinery, it would no doubt be a desideratum in the process of blowing. It will appear from these facts, that in summer, when the quantity of air is deficient from increase of volume, and from the presence of water, that a larger quantity of air should be made to enter the furnace, partly by increasing the velocity, and partly by using a *nose-pipe* of greater diameter. If the deficiency were made up by the increase of pressure only, the velocity would be too great for producing a maximum of combustion, where it is immediately wanted, independent of the mechanical evil it would be liable to produce. If, on the other hand, the aperture of the *nose-pipe* were increased in summer, to make the quantity equal to that of winter, the air would enter in a state of greater rarity, and the combustion would, from this cause, be of less intensity. This circumstance alone, perhaps, is sufficient to prevent a complete remedy of the evil, and will go far to explain the difference between the fractions resulting from calculation and experiment.

We shall conclude our account of this department of iron-manufacture with some general observations upon the nature and properties of pig-iron, as it is applied to different purposes.

When the iron has combined with its full dose of carbon, constituting what is called in the trade, grey, or smooth-faced iron, and also N° 1, it is admirably fitted for making the lighter and finer sort of castings, such as grates and other ornamental work. It is from iron of this quality that the cast-iron cutlery is manufactured, since no other would run sufficiently fluid for articles so small as the prongs of forks, and the bows or rings of scissors. This iron, however, is not the best for larger castings where strength and hardness are desirable; as in large wheels, for example, beams, pillars, railways, &c. The metal employed for these purposes contains a lesser proportion of carbon than the former, and is generally called melting-iron, or N° 2.

That species of pig-iron, however, which is combined with the smallest dose of any, is almost exclusively employed for making malleable iron, and is called, for that reason, *forge-pig*. We have given, in the next section, an account of the proportion of carbon present in the different varieties; and it will appear from thence, that of all the combinations of iron and carbon, steel contains the least, and grey, or N° 1, pig-iron, the most of any of the compounds we are yet acquainted with.

As a proof that pig-iron only requires to lose its carbon to become malleable, we have at present in this country manufactures upon a large scale, for converting cast metal goods, such as nails, cutlery, &c. into iron perfectly malleable, without even changing the figure given to them by casting. Nails produced in this way are so malleable, even when cold, as to bear the hammer, and are capable of being bent to a right angle in a *vice*.

But a still stronger proof that this metal assumed the form of iron is from the great heat it will bear. The prongs of a common fork made by this process can be welded together with the greatest facility. Pig-iron, until lately, has been considered a much more complex body than experience has warranted. We have heard of its being supposed to contain silex, or, according to Mr. Davy, silicum, to which it owes some of its crude qualities. But the process just mentioned is sufficient to refute the assertion. Iron masters, even at this day, however, will talk about oxygenated pig-iron, meaning that which is least carbonated; but it must be clear to every one acquainted with the chemical qualities of those bodies, that the presence of carbon and oxygen in a liquid mass is perfectly impossible, as they are incapable of existing together uncompounded at any such elevated temperature. Hence we must regard pig-metal as a compound of iron and carbon only. Manganese may perhaps sometimes be present in it, when particular ores are employed for smelting, but its union must be considered as accidental.

To make pure iron, therefore, we have, from these conclusions, only to extricate the carbon. This may be done, in small masses, by stratifying the articles in a close vessel with some substance containing oxygen. The poorer iron ores, which are free from sulphur, are used in powder for this purpose; and after the materials have been exposed to a heat just short of the fusion of the metal, the air being completely excluded, the carbon will become dissipated, and the iron left in a state of purity. See CASTING and FOUNDERY.

§ 4. *Conversion of Pig-iron into malleable Iron, and Steel.*

1. *Bar, or wrought Iron*.—Iron, as obtained by the reduction of its ores in the blast-furnace, contains, as we have before stated, a certain proportion of carbon, which renders the metal unfit for the various purposes of forging, but constitutes its principal value as applicable to the use of the founder. To deprive it of this ingredient certain processes are gone through, the object of which is, by the concurrent action of heat and air, to dissipate the carbon under the form of an elastic compound. The kind of iron chosen for the conversion is that denominated by manufacturers *forge-pig*. It is the lowest quality made for the purposes of art; and, in consequence of its being combined with a smaller dose of carbon than any other, which thus causes it to bear a less price in the market, is doubly preferable for the end required.

The price of *pig-iron* is almost exclusively determined by the quantity of carbon which is in combination with it. The varieties usually distinguished are N° 1, otherwise called *grey*, *smooth-faced*, or *kishy*, metal; N° 2 and 3, and *forge-pig*. The proportion of carbonaceous matter present in these varieties is differently stated by different experimentalists. Clouet makes the highest proportion to amount to $\frac{1}{4}$th; but from the results obtained by Mr. Mushet in combining iron *directly* with the doses of charcoal requisite to produce its various sub-carburets, $\frac{1}{15}$th appeared to be the *maximum*. Of this, the following table, published by him in the 13th vol. of the Philosophical Magazine, will afford the necessary proof.

Soft cast-steel - - - - - -	$\frac{1}{120}$
Common ditto - - - - - -	$\frac{1}{100}$
Same, but harder - - - - -	$\frac{1}{90}$
Ditto, too hard for drawing - - -	$\frac{1}{50}$
White cast-iron (same as before called *forge pig*)	$\frac{1}{25}$
Mottled cast-iron (N° 2.) - - - -	$\frac{1}{20}$
Black cast-iron (N° 1.) - - - -	$\frac{1}{15}$

The first step in the process of decarbonization, according to the more common mode of operating, is to expose the iron in a

furnace, called by ſome a *refinery*, but by others, to diſtinguiſh it from one hereafter to be deſcribed, a *run-out furnace*. It conſiſts of a veſſel open at the top, imbedded in ſtone or brick work, about two feet three inches long, two feet wide, and ten inches deep. This is generally, in part, conſtructed of caſt iron; and, when ſo made, has an outer caſe about two or three inches diſtant from the inner one, which is conſtantly ſupplied with a ſtream of cold water to prevent the apparatus from melting. The iron to be decarbonized is placed in this receptacle, and kept in a continual ſtate of fuſion for three or four hours by the aid of a coke fire, which is heaped to a conſiderable height above the level of the veſſel, and extended proportionally on the hearth that ſurrounds it. The ſize of the hearth is moſtly about three yards in length, and from two to three wide, and is completely covered by the funnel of the overhanging chimney. Bellows of conſiderable ſize are employed to carry on the proceſs; and the current of air which iſſues from them is directed immediately on the ſurface of the iron by one or more *tuyeres*. Theſe *tuyeres* are double, like the caſe, and continually cooled by the application of the ſame means. When the decarbonization is completed, the metal is let out at an opening in the ſide, which has been kept cloſe during the operation by a *ſtopping* of ſand. It flows into a groove about 18 inches wide, and ſix or ſeven feet long, conſtructed of ſtone in the floor that ſurrounds the furnace. The bottom of the veſſel is ſo placed as to be nearly on a level with the floor; the only elevation given to it being what is merely ſufficient to let the iron run out with facility. A conſiderable quantity of vitreous oxyd is formed during the proceſs; and the loſs in the weight of metal, which is ſtated to amount to from $\frac{1}{6}$th to $\frac{1}{7}$th, is principally referable to this circumſtance. The total quantity of carbon which the iron contains originally is not eſtimated at more than $\frac{1}{15}$th; and yet the approach of it to the pure ſtate, or, in technical language, to the ſtate of *bar* or *wrought-iron*, after this operation, is very inconſiderable.

The cake of metal procured by theſe means is broken into lumps of a convenient ſize, and ſubjected, in a furnace of another deſcription, to a proceſs known in the art by the name of *puddling*. The furnace, which is alſo diſtinguiſhed by the ſame term, is a variety of the reverberatory; and at the immediate point where the flame ſtrikes upon the hearth, a ſhallow concavity is worked out, in which the melted iron is expoſed. Oppoſite to it is a door, and through this the metal is kept in continual agitation, by means of a ſort of rake, for the purpoſe of exhibiting freſh ſurfaces perpetually to the influence of the air. Water is likewiſe occaſionally thrown in, which in ſome degree contributes to the decarbonization. With the loſs of carbon, the iron alſo loſes its fuſibility, and about the middle ſtage of the operation appears in the form of ſmall detached lumps, which ſcarcely ſeem to exert any affinity for each other. At length, however, by much ſtirring, and frequently preſſing them together, they cohere into a pulpy maſs; and being gathered into pieces of a convenient ſize, are carried under rollers, where, after paſſing through four pairs, in ſucceſſion, of a gradually diminiſhing guage, they are produced into plates ſeven or eight inches wide, and three feet or more in length. Conſiderable quantities of matter are ſqueezed out in the rolling, which principally conſiſt of a vitreous kind of oxyd. This is, for the moſt part, to be referred to the action carried on in the furnace; but ſome portion of it is, in all probability, created by the combuſtion of ſmall pieces of fluid metal, which, engaged amongſt the particles of the *puddled* maſs, are hurled through the air in a ſtate of vivid inflammation, by the compreſſive violence of the rollers. The total loſs thus ſuſtained is eſtimated at from $\frac{1}{6}$th to $\frac{1}{7}$th. The plates obtained by this treatment have a very incompact appearance; and if attempted to be worked in the ſtate they are then preſented under, would crumble almoſt wholly into ſmall granulated lumps. To impart to them the neceſſary cloſeneſs and ſolidity, they are again heated in another kind of furnace, and beaten forcibly with a heavy hammer, which is raiſed by machinery.

Previouſly to being thus treated, they are broken up into cakes of ſmall ſize, and placed upon circular ſlabs of ſtone from 8 to 12 inches in diameter. The ſize of the cakes is in a great meaſure determined by a particular effect of the laſt pair of rollers that they are paſſed through: ribs, of a diamond ſhape, girding either one or both of them, on the whole extent of their ſurface, which leave a deep indentation on the plates, ſo as to render them eaſily frangible in that direction. The height to which theſe cakes are piled on the circular ſlab juſt ſpoken of, is generally about 12 inches; and when ſo prepared, they are placed on the hearth of a reverberatory furnace, which differs but little in form from that employed for *puddling*, except in being flat at the bottom inſtead of concave. The furnace is denominated a *balling furnace*; and the piles of metal, *pies* or *balls*. They are continued in this ſituation until they have arrived at a welding heat, and are then removed by large tongs under the ſtroke of the hammer. Near to the place a ſmith's forge is kept in blaſt, where long bars of iron are alſo urged to the welding point; and, after the firſt ſtroke or two of the hammer, united to the *balled* maſſes, to afford greater convenience in turning them. The maſſes are beaten out into ingots of about three feet in length; and the bar laſt mentioned being ſeparated, they are divided deeply by an inſtrument termed a *ſet*, to facilitate their being afterwards broken; and the proceſs is then completed. They are in this ſtate called *blooms*, and have yet to undergo another operation, for the purpoſe of being made into bars or plates. Much loſs is ſuſtained by the laſt treatment, and principally from the ſame formation of oxyd as was noticed in the preceding caſe. The quantity thus loſt, added to the waſte occaſioned in the *bloomery*, which comes next to be deſcribed, is uſually conſidered as equal to $\frac{1}{5}$th of the metal obtained by *puddling*; which will make the total deficiency, by all the operations, as nearly equivalent to ^{35}. The ingots or *blooms*, which are received from the hammer, after being broken, over a ſmall wedge-ſhaped block of iron called a *tup*, are placed in a ſpecies of reverberatory, very ſimilar to the *balling furnace*, and denominated a *blooming furnace*, or *bloomery*. They are here heated to welding, and then ſubmitted to the requiſite preſſure under rollers, which are either plain or grooved, according as the iron is wiſhed to be obtained in plates or in bars. This completes the whole of the proceſſes neceſſary for making the beſt malleable iron; and it reſults from the obſervations which have been premiſed, that, in order to procure one ton of it, five-and-thirty hundred weight of *forge-pig* is previouſly required.

Two other modes of operating are at preſent in uſe; one of which omits the *puddling*, and the other, that part of the foregoing proceſs that concerns the fabrication of *blooms*. In the former, iron is expoſed to the heat of a charcoal fire, in a ſpecies of furnace preciſely ſimilar to the one before deſcribed as a *refinery*, or *run-out furnace*; and is continued in that ſituation, until the metal is thought to be ſufficiently decarbonized. It is very frequently ſtirred during the operation; and when brought *into nature*, (to uſe the technical expreſſion,) is collected into maſſes, and removed by

tongs under a large hammer, denominated, as applied to this particular use, a *stamping hammer*, where it is beaten into cakes, which are afterwards broken up, and treated in the *balling furnace* as before described. This is the old mode of working, and the iron obtained from it is by many conceived to be of very superior quality. The heat produced is considerably inferior to that afforded by coke in the *run-out furnace;* and the iron is less surrounded by the fuel than in the case just mentioned. The present charcoal fire is properly a *refinery*, and not the one which is used merely as a preliminary to the process of *puddling*. Here, the business of decarbonization is at once completed; and the resulting metal is in the same state of purity as that yielded from the rollers, after it has been *puddled* by the other method. *Balling* and *blooming* follow in regular succession, and plates or bars are produced exactly as before.

According to the second mode of treatment, in which *blooming* is omitted, the masses obtained from the *balling furnace* are reduced under the hammer into the form of solid, cubical blocks; and when their temperature is too much lowered to be capable of any farther working, they are again heated in a fire called a *chafery*, which is urged by a powerful pair of bellows, and scarcely differs from a common smith's forge, except in being larger, and the cokes upon it being heaped up to the unusual height of at least two feet. In this situation they are raised to the point of welding, and afterwards hammered out into ingots of a flattened shape. Iron bars are united to them very shortly after they are brought from the *balling furnace*, to afford a greater facility of management, in the same manner as was described in the making of *blooms;* and these, as before, are detached, when the ingot is sufficiently formed. The iron produced in this way is not considered so good as that afforded by either of the other processes, and is employed, for the most part, in the commoner services of art. Repeated rolling, or hammering, is the only means of imparting the fibrous texture so necessary to good bar iron; and as this treatment is less frequent in the present mode of operating, the deficiency of value in the material obtained may very probably be referable almost exclusively to this circumstance.

The above include the whole of the *important* variations that are presented in the manufacture of bar iron. Other shades of disagreement may be traced in different works; but they are of a nature too trifling and unimportant to merit any particular enumeration. The art is still in its infancy; and the light of chemical science, by being brought to a focus here, cannot fail to disclose many improvements in the present modes of procedure, which will greatly abridge the expence now incident to this valuable branch of national industry. That the mere abstraction of about 4 *per cent.* of carbon should require a sacrifice, in effecting it, of above 40 *per cent.* of iron, appears monstrous beyond example: and as those who are connected with the art become more scientific in their views, we shall unquestionably find that it will be much more economically accomplished.

When iron has been completely freed from carbon, and has acquired its highest degree of malleability by repeated hammerings, it is by far the most tenacious of all the metals, and is capable of being drawn into the finest wire.

The tenacity of iron, as well as of all the rest of the malleable metals, varies considerably according to its softness. After iron has been kept in a red heat for some time, and suffered gradually to cool, it becomes remarkably changed in point of softness. By being hammered, drawn into wire, or rolled, it increases in hardness to a certain extent; but, at the same time, partly loses its malleability. By this mechanical treatment, when cold, its strength or tenacity increases; and it may be taken at one point, when it will require a far greater weight to break it, than if it were hammered either more or less.

All the experiments yet published relative to the tenacity of iron, and the other metals, are on this account very defective. The writer of this article has seen an iron wire, when newly annealed, break with a weight of 50 pounds; but, after being drawn through two holes of a wire plate, bear above twice that weight, without sustaining injury. Iron, when properly annealed, will bear more bending backwards and forwards before it breaks, than in any other state: but the strength, or that power which resists a weight, exerted longitudinally to break it, is jointly as the last property and its hardness. Hence the reason why its strength is increased with a certain degree of hammering. The specific gravity of malleable iron, according to Brisson, is 7.788; that of pig iron being 7.207. Iron, in a state of purity, requires so great a heat for its fusion, that the best crucibles are nearly ready to melt with it. It has, however, been fused, and cast into an ingot. It is said to liquify at 158° of Wedgewood. Its malleability is greatly increased by heat; and by raising it to a very high temperature, it becomes exceedingly soft, and may be brought so near to absolute contact with another piece similarly heated, that they unite firmly together. This process is called *welding*. Its great affinity for oxygen, when heated to a welding point, would very soon reduce it to an oxyd, if it were not for the vitreous matter fusing upon its surface; and it may be still more completely defended, by dipping it in powdered glass or sand. See *Description of Plates* at the end of the article.

2. *Steel.*—This substance, which is a compound of iron and carbon, but in less proportion than that of pig iron, is of such distinguished importance in most of the arts, that no other substance could be substituted, capable of supplying its united properties of hardness, tenacity, and elasticity. After the pig iron is totally deprived of carbon, and becomes malleable, the metal can be re-impregnated with that substance to a certain extent, without losing much of its malleable property.

It is curious to remark, that although we have made iron of excellent quality in this country, for all the nice purposes to which it is capable of being applied, yet, in attempting to convert it into steel, we have always failed; the steel being red-short, and otherwise bad. It, of late, however, has been so great a desideratum to obtain steel from British ore, in consequence of our want of communication with Sweden and Russia, that several efforts have been lately made to bring about this desirable object, and not altogether without success. We may yet entertain a hope, therefore, that the time *will* arrive, when we shall not be dependent on other countries for this useful commodity.

The only steel at present, on which perfect reliance can be placed, is made from some of the best marks of Swedish iron. The bars are stamped with certain letters or characters, well known to the steel-makers; and some of them have preserved their character for making good steel during a long series of years.

The size of the bars varies from 3 inches broad and $\frac{1}{2}$ inch thick, to about 2 broad by $\frac{1}{16}$ thick.

Nothing more is necessary to impregnate the bars of iron with carbon, by which they become steel, than to stratify them with powdered charcoal in a close vessel, called a cementing pot; exposing the same to a degree of heat as little short of what would fuse the steel as possible.

The furnace in which the procefs of cementing bar iron is performed is called a converting furnace.

The pots are made of a peculiar ftone called fire-ftone, from its joint property of not being liable to crack by the heat, aud its little difpofition to enter into fufion. It is a fine grit, and occurs abundantly in the neighbourhood of Sheffield. The interior of thefe pots is in dimenfions from 12 to 15 feet long, and from 2 feet to 30 inches fquare. Every furnace contains two of them; and they generally hold about 5 tons of iron each. The metal is ftratified with the charcoal duft, in fuch a way that each bar may be completely covered; and the laft ftratum, which fhould be thicker than the reft, is kept clofe with a mixture of clay and fand, fo as to prevent the charcoal beneath it from entering into combuftion with the outer air.

The fire is then gradually applied, and the exterior furface of the pots conftantly enveloped with flame, till the whole mafs has become of the heat required. This heat is kept up for a confiderable time, fo that from the commencement of firing to the maximum is about feven days. The fame fpace is afterwards required to allow the mafs to cool. This rule, however, is not fufficient to tell when the cementation is perfect. A hole is generally left in the front of the furnace, paffing through the wall to the interior of the pot. One or two bars are laid with their ends projecting into the opening, which is loofely fil'ed with powdered charcoal. When the procefs is fuppofed to have gone on long enough, one of thefe bars is drawn out and examined.

All bar iron muft, owing to the manner in which it is made from the pig, contain a fmall portion of oxyd of iron, as well as fome remains of iron not completely deprived of its carbon. The long continued heat which this procefs requires, cannot fail to caufe an union between the oxygen and carbon, accidentally exifting in the bars; and we may expect, in confequence, that an elaftic fluid will be formed, which muft be either carbonic acid or the carbonic oxyd; but fince the oxyd is in the ftate of finery cinder, we fhould rather conceive it to be the latter; and we believe experience warrants the conclufion.

This elaftic fluid, when the metal is fo near the fufing point, caufes the furface of the bars to be covered with blifters, which are a fure fign that the cementation is complete: and it is from the number and fize of thefe blifters, that the workmen know when to ceafe adding fuel to the furnace.

Steel is made of different degrees of hardnefs, by giving it more or lefs carbon; and this is effected by keeping up the heat a longer time, ftill having regard to the quantity and fize of the blifters.

The fteel ufed for coach-fprings contains the fmalleft quantity of carbon; a fomewhat greater proportion is required for table knives, forks, carpenters' tools, and agricultural implements; and the largeft dofe of all is wanted for files, which can fcarcely be too hard, if the fteel be fufficiently malleable to work.

Steel, in the ftate it comes from the cementing furnace, is called *bliftered fteel,* from the appearance we have juft defcribed. It is not ufed but for common purpofes, although formerly we had no other kind. The bars of iron being formed under the forge hammer, and produced in a country not remarkable for the excellence of its machinery, the metal is found to abound with numerous feams and fhells, which good workmanfhip might in a great meafure avoid.

This evil is, however, very happily remedied, by making the bliftered-fteel into what is called *fhear-fteel,* and *caft-fteel.*

Shear-fteel has derived its name from the advantage with which it has been applied in the manufacture of fheep-fhears. Its admirable property of welding to iron, without the other qualities it poffeffes being injured, renders it of great importance in all cafes where the body of the edge-tool is conftructed of iron, and the edge merely fteel.

From having been firft made at Newcaftle-upon-Tyne, it has alfo been called *Newcaftle fteel.* The apparatus ufed for its manufacture confifts of a pair of bellows, or other blowing machine, and a fire place fimilar to that of a fmith's hearth, but upon a larger fcale. The hammer for drawing the bars is larger than a tilting hammer, but fmaller than the one employed at an iron forge.

In order to make fhear-fteel, a number of bars of the beft bliftered-fteel are laid together, and temporally faftened. In this ftate they are introduced into the fire, and heated to a welding temperature; after which they are firmly united by means of the hammer, and drawn. At a fecond heat thefe maffes are beaten down into bars about 1½ inch broad and ⅜ths of an inch thick. By this procefs the loofe parts and feams of the bars are clofed together, and the fteel is rendered fufceptible of a polifh, of which before it was not capable. But thefe are not the only advantages. The additional hammering fo far improves its malleability, that the tenacity it enjoys is much greater, while its hardnefs is very little lefs.

This fteel is particularly adapted for fprings of every defcription, and for all edge-tools requiring great tenacity rather than hardnefs.

Caft-fteel is entirely free from the mechanical defects which belong to bliftered-fteel, and even, in fome degree, to fhear-fteel; fince it confifts of the latter variety completely fufed, and caft into ingots.

The furnaces employed for this purpofe fhould poffefs all the advantages which can be given to air-furnaces, on account of the great heat requifite for the procefs. (See FURNACE.) The crucibles, in which the fteel is melted, are made of Stourbridge clay, mixed with a fmall quantity of powdered coke, which makes them lefs liable to crack in the heating or cooling; and, at the fame time, gives to them a confiderable degree of ftiffnefs in the fire, when raifed to the very great heat required. Thefe crucibles are furnifhed with covers, which are of rather more fufible clay than the body of the veffel, and, on that account, are foon partially vitrified; by which means they become clofely luted at the time the fteel is at a temperature fufficiently high to be deftroyed by the oxygen of the atmofphere.

The fuel employed for melting fteel, confifts of the hardeft cokes, and in all cafes where long continued and high temperatures are neceffary, cokes of this defcription fhould always be employed. Two advantages attend the ufe of them; for although the foft cokes produce a very great heat during a fhort fpace, yet the length of time required for melting fteel would oblige the workman to charge the furnace too often; fo that he would ultimately get a greater heat by the permanence of the hard coke; and the fpecific gravity of the latter is fo much greater than the foft, that the fuel is more condenfed, and hence, allowing for the difference of cohefion, will give more concentrated heat, if the fupply of air be fufficient.

The crucibles are of a fize fufficient to hold about 30lbs. of fteel; and, in general, each will bear charging three times, or even four: fome would remain found ftill longer than that, if the fires were continued; but they are feldom

kept in more than twelve hours in the day, and this will not allow of more than three heats. For the best possible cast-steel, the bars of the best blistered-steel are broken into small pieces, it being, on coming from the cementing furnace, sufficiently brittle for this purpose. An inferior kind of cast-steel is made from the scraps, which consist of the waste of the manufactories. The heat required to melt steel is very great; and inversely as the quantity of carbon combined with it. Before cast-steel making was brought to great perfection, the quantity of carbon given to it was greater, in order to effect its more easy fusion. The crucibles and furnaces, however, are now so much improved, that the steel can be melted with much less carbon, and it is, in consequence, so *kind*, to use a technical phrase, as to weld with iron, and even to be capable of uniting two pieces of it together.

After the steel has become sufficiently fluid, it is poured into cast-iron moulds, which form it into ingots of an octagonal shape; and are about 30 inches long, each weighing about 30lbs. Formerly, the great secret of making cast-steel was said to consist in using some peculiar flux. No substance, however, from what has been observed, can increase the fusibility of the steel, but an additional dose of carbon, which is improper after a certain quantity has been united with it. The only substance, therefore, which can be employed to any advantage, must be some fusible vitreous matter, capable of floating upon the surface of the metal, and defending it from the contact of air.

The flux at present used, and the most proper for this purpose, is the blast-furnace cinder. But pounded glass, or any vitreous substance which fuses a little before the metal melts, will answer equally well.

The ingots of cast-steel, as well as the bars of blistered-steel, and shear-steel, are drawn into rods ready for forging into various articles, by a piece of machinery called a *tilt*, or *tilting-mill*. (See TILTING-MILL.) By this hammer, the cast-steel can be drawn down to the size of ½ inch square. But in reducing smaller than that, it would be liable to be injured in its fabric. It is drawn into rods of smaller size by hand, for the purpose of making gravers, and watch-makers' tools: and for still more delicate articles, it is manufactured into wire. The blistered-steel will not bear drawing to a small size, on account of the looseness of its texture.

Steel is of a mean specific gravity between wrought and pig-iron; and, like the former, it increases its property in this respect by hammering. Like iron, too, it becomes softer on being annealed, but never becomes so soft as that metal. When of good quality, and at a certain degree of hardness, it is stronger than iron; that is, when stretched longitudinally by a weight; but, by sudden bending or twisting, it is more liable to break short. In working it with the hammer, it will not bear so great a heat as iron; since the temperature iron and its combinations sustain without melting, is inversely as their dose of carbon.

This property of bearing heat, is, however, in a still less ratio in cast-steel. This is owing to its having entirely lost its fibrous form in the melting. Hence there is less danger in heating it after it has been hammered.

In welding steel to iron, or steel to steel, the fire ought to be very free from sulphur, or other extraneous matter; and the heated parts of the rods should be frequently supplied with either sand, or sand mixed with the scales which come from the hammered iron. This fuses upon the surface and keeps off the air. See FORGE.

The most singular property which belongs to steel, is that of its hardening by being heated red-hot, and cooling rapidly. This change is greater the hotter the steel, and the colder the fluid into which it is plunged. (See CUTLERY.) Water, in general, is employed for this purpose; and spring-water is better than any other. If the water abound with animal or vegetable matter, the hot steel cools more slowly. This is occasioned by a film of the matter in solution forming and remaining upon the surface, and, being a bad conductor of heat, prevents the steel from cooling. File-makers say, that the salt which is inevitable in their hardening water, makes the steel harder, and they sometimes put sulphuric acid into it for the same purpose.

In hardening steel in thin plates, such as saws, particularly when of cast-steel, quenching in water would cause them to crack, and make them so hard as not to be useful. They have, in consequence, recourse to some substance which is not so good a conductor of heat. Oil, with tallow, bees' wax, and resin dissolved in it, is generally employed for these articles. (See the article SAW.) If the steel be heated red-hot, it mostly returns to its original state. This, however, is sometimes not the case with thin plates of cast-steel. In giving various degrees of heat from the hard state, it becomes more soft and less elastic. See CUTLERY.

This curious and valuable property which it possesses might, at first view, appear to be caused by an increase of density; but the specific gravity of hardened steel is less than before it is hardened. It has been said to depend upon a certain crystalline arrangement of its particles; but this is a mere apology for ignorance. The most plausible theory we have heard of is mentioned in one of Dr. Darwin's notes to his "Botanic Garden," and was the idea of a very ingenious friend of that celebrated author. This theory was equally applied to the singular property possessed by the glass toys known by the name of *Prince Rupert's Drops*. It is as follows. When the heated steel or glass is plunged into water, the exterior stratum becomes so hard and solid, as not to be capable of shrinking; and every succeeding layer is to a certain degree placed in the same situation. When caloric leaves a body slowly, it contracts in its dimensions, until it assumes something near its original volume. But if any force prevent the parts from approximating, the molecules will attract each other with a power equal to the repellent energy of the caloric that caused the expansion. So soon, however, as the outer stratum is broken, the whole of the others are destroyed in succession. This is most glaringly the case with the glass drops before spoken of, and, to a certain extent, with unannealed glass, and hardened steel.

With respect to the latter, however, it is confined to large masses, and particularly of cast-steel. The rollers employed by jewellers and others are of cast-steel, and are very liable to break in the hardening, although about half the mass in the middle is pure iron. They do not always crack at the time, but at different periods afterwards, and frequently, when no violence is applied to them, some have been known to fly six months after being finished. Sometimes they break with great report, and what strengthens the above opinion as to the cause is, that the figure of the roller is frequently changed from a round to an elliptical shape. For farther particulars, see STEEL.

§ 5. *Chemical Properties.*

When a piece of polished iron is exposed to the air, it soon loses its lustre; and if the atmosphere be humid, it becomes covered with red spots called *rust*. When it is exposed at 400 degrees of Fahrenheit, it changes to a yellow colour. The temperature being increased, the colour gradually turns to a brown, and at the heat of about 600° it becomes of a beautiful blue tint. This change of colour arises from the combination of oxygen;

the quantity increasing with the temperature. If the surface be defended by a coating of chalk and a solution of glue, no change of colour takes place when the heat is applied. In the art of blueing steel, advantage is taken of this method to make the blue ornamental.

In a higher temperature the surface becomes covered with a scaly crust, which is composed of oxygen and iron; and in the heat of a smith's forge, it combines with oxygen so rapidly as to burn, throwing off sparks in bright corruscations. If small iron wire be exposed in pure oxygen gas, the end being ignited with a bit of greased cotton, the metal enters into brilliant combustion, and a globule of melted matter is formed at the end of it. The iron so burnt loses all its metallic properties, by combining with the oxygen; and during this change the phenomena of burning take place. The globule is so brittle as to be capable of being reduced to powder, and is called the black or vitreous oxyd of iron.

Iron has so great an attraction for oxygen, that it decomposes water even in the cold. When filings of that metal are mixed with water in a vessel connected with a pneumatic apparatus, an elastic fluid is evolved, which is found to be hydrogen. The iron loses its metallic lustre, and ultimately is converted into the black oxyd before spoken of.

If this mixture be in a retort, and the boiling heat applied, the iron combines with the oxygen of the water with much greater rapidity; and, of course, a much greater quantity of hydrogen is eliminated. This method has been employed to obtain the black oxyd of iron, which was formerly called *Martial Ethiops*. Iron decomposes water with very great rapidity, when the sulphuric or muriatic acid is present. The acid takes up the oxyd as it is formed by the agency of the water, and a new surface is constantly presented. A large quantity of hydrogen is in this process disengaged, and it is by the present method that this gas is procured for filling aërostatic machines, and for other purposes. If the oxyd which is taken up by the acid be precipitated by an alkali, and dried instantly, it will exhibit a similar appearance to that obtained by the action of water alone. When first separated it has a green appearance, which it owes to the presence of water; and this being dissipated by heat, it is left of a dark-grey colour. This oxyd, formed by either of the above processes, is called the prot-oxyd of iron, because it is combined with the *first* or smallest dose of oxygen. According to Proust and Lavoisier, it consists of 73 of iron, and 27 of oxygen.

If the prot-oxyd of iron be exposed to the air in a red heat for a length of time, it assumes a red colour, and constitutes the substance known in the arts by the names *crocus* and *colcothar*. This change of colour is found to have been caused by its combining with an additional dose of oxygen, and the product is denominated the peroxyd, consisting, according to Proust, of 52 iron, and 48 oxygen. From the best chemical authorities, it appears that iron unites with oxygen only in two fixed proportions, constituting the prot-oxyd and the peroxyd; although it has been held by some that there are more varieties.

If a bar of iron be heated red-hot, and a stick of sulphur applied to it, a fluid substance will drop from its end, which is found to be compounded of sulphur and iron, and in chemistry is called sulphuret of iron. The fusion of sulphur and iron-filings, in a crucible, gives a similar product. The attraction between these substances is so great, that their union in nature is very common.

Iron-filings, mixed with sulphur, and made into a paste with water, in a certain time become very hot and even produce flame. The mixture is sometimes buried under ground to produce an artificial volcano. This phenomenon, however, does not depend upon the immediate combination of the sulphur with the iron. The water, which is a considerable agent, is decomposed; the oxygen uniting with the iron to form an oxyd of iron, and with the sulphur to form the sulphuric acid, while the hydrogen combines with another portion of the sulphur producing sulphuretted hydrogen, which occasions the flame in the experiment.

When iron-filings are heated with sulphur, even where oxygen is not present, at a little short of the temperature of redness, they combine and produce flame. We are indebted to the associated Dutch chemists for this fact, as well as a similar experiment with sulphur and copper.

The artificial compound of sulphur and iron, from the experiments of Proust, is composed of 62.5 sulphur
37.5 iron

100

The native sulphuret is found to contain a greater proportion of sulphur. When heated in a close vessel, some of the sulphur sublimes, and may be collected in a proper apparatus. By this treatment, it is reduced to the state of common sulphuret, and loses 20 *per cent.* of its weight. It is hence composed of 50.6 sulphur
49.4 iron

100

According to some experiments made by Mr. Hatchett, however, these proportions are not regular in specimens where the crystalline form varies. This ingenious chemist has found a native species agreeing in the proportion of its constituents with the artificial sulphuret. It is what has been called magnetic pyrites; and is by this test of the magnet distinguished from the common pyrites, which does not possess that property. It has also another peculiar character. If dilute sulphuric or muriatic acid be poured upon it, a rapid action takes place, and sulphuretted hydrogen is evolved. This is not the case with the super-sulphuret till it has been exposed to heat, when it loses its excess of sulphur. The common sulphuret of iron has been employed to make artificial magnets. Mr. Hatchett found that not only the sulphurets, phosphurets, and carburets, were separately magnetic; but suspects that certain proportions of all these may constitute a *maximum* of magnetic virtue.

It is highly probable, that the iron is the only substance possessing magnetism; and that the facility with which these compound substances become magnetic, may arise from the greater ease with which the particles of iron assume the peculiar arrangement on which this curious property depends. That some arrangement, though perhaps equally mysterious with crystallization, may be the cause of magnetism, there is much reason to believe. By mixing iron-filings with melted resin, and inclosing them in a brass tube, if a magnet be brought near to the tube, while the mass is still liquid, the whole, when cold, will become a magnet. During the touching of a piece of steel to make it magnetic, there is little doubt but that a new and peculiar disposition takes place amongst the particles, notwithstanding the solid state of the metal. The particles of bodies appear to be free to motion in the solid form. We find that iron combines with carbon, while both bodies are in that state; and what is still more curious, the compound assumes a different crystalline structure, according to the proportions of the two bodies. Oxygen appears, in some instances, to alter the internal arrangement of solid bodies. If brass, for example, were to be kept in a damp room, but more particularly where the fumes

of acids are present, the metal, although previously very tenacious and ductile, becomes so brittle, as not to bear bending to a right angle; at the same time that the broken surfaces exhibit a crystalline fracture. That species of form, therefore, under which magnetism exists, may be brought about by various means. All iron instruments, kept in one position for a length of time, become magnetic; especially if that position coincide with the magnetic meridian. We regret that so little is known on this interesting subject; and for farther particulars refer to the article MAGNETISM.

Iron combines with several of the metals forming alloys, none of which have very striking or useful properties The alloy of iron and gold has been examined by Mr. Hatchett, who found that 11 parts of gold to 1 of iron formed a malleable alloy, remarkably ductile, so as to roll into plates, and be capable of being stamped into coin. The colour was of a pale yellowish-grey, and it was of the specific gravity of 16.885. The most singular property of this alloy is its increase of volume by combination. Before the union, the bulk was 2799; and afterwards, 2843. The very contrary is the case with most of the other alloys of metals, and agreeably to Berthollet's doctrine of affinity, we find that the mean specific gravity of bodies by experiment, is greater than the arithmetical mean, directly as the affinity of the bodies. We should, therefore, in this instance conclude, that either the affinity of the metals is trifling, or that the above law is not general.

The alloy of pure iron with platina has not been effected from the great infusibility of the two metals. Dr. Lewis alloyed cast iron with platina, as well as steel. The specific gravity of this alloy, contrary to the last, was greater than the arithmetical mean. It was very hard and tenacious, possessing some degree of ductility.

After being kept ten years, it was little tarnished. Iron is easily alloyed with silver. In equal parts they form a compound of considerable ductility, of the colour of the latter metal, but much harder; and is attracted by the magnet. The metals separate, in some degree, when kept in fusion; but, according to the experiments of Morveau, not completely; the silver retaining some of the iron, and the iron some of the silver, by which its quality, as a metal, is much improved. Iron is not easily combined with copper in large quantity. We find, however, that these metals are capable of uniting, and the alloy is, in some degree, magnetic. Indeed, in forming certain instruments of brass, where the magnetic needle is employed, they are frequently defective from this circumstance. To free copper entirely from iron, it should be redissolved in an acid. The oxyd, after precipitation, should be dissolved in aqua ammonia, and the alkali then distilled from it. This being afterwards treated in a close vessel with some inflammable matter, the metal will be obtained pure. The alloys of tin and iron, and that of iron with zinc, may be formed by mixing clean iron-filings, or turnings, with those metals while in a state of fusion. These compounds are not of any use. Iron may be soldered with several of the metals Copper, gold, and silver, unite to it with great facility; but require the presence of borax to keep off the air.

The most permanent solder for iron is the carburet of the same metal, called N 1, pig-iron. The pig-iron loses some of its brittleness, and the malleable metal becomes much harder. It does not appear improbable that steel might be formed by uniting these two substances together in certain proportions.

We have next to treat of the salts of iron, or its combinations with acids.

Sulphat of Iron.—Sulphuric acid does not combine with iron in its metallic form; in conformity with the general law that no acid unites with a metal till the latter is previously oxydated. Iron is but slightly acted upon by this acid in the cold; but with a degree of heat far short of boiling, the iron takes from it a portion of oxygen, converting it into the sulphurous acid, which escapes in the form of gas. The iron, thus oxydized, combines with another portion, and forms the sulphat of iron.

When water is added to the iron and the acid, a much more rapid action takes place. The metal seizes the oxygen of the water; hydrogen is evolved; and the acid unites with the oxyd forming the salt in question. When the product obtained by this means is more than the water can dissolve, it assumes the form of green crystals, which, when separated, are the same with those known in commerce and the arts by the names of *green vitriol* and *copperas*.

In the action of iron upon the concentrated sulphuric acid, it appears anomalous, that the metal should not be oxydized with more facility by this acid, when water is so rapidly decomposed, the elements of which have so strong an attraction for each other. It may appear equally strange that the water is not decomposed when the acid is not present. When it is recollected, however, that the oxyd of iron is not soluble in water, nor sulphat of iron in the acid, it will appear very clear that the two substances are both essential to the effect; the acid promoting the decomposition of the water by taking away the oxyd, and the water taking up the salt, which would be equally obstructive to the process.

This salt is not commonly obtained by the above process. The sulphuret of iron, above described, already consists of two of its elements, namely, sulphur and iron; the oxygen and water of crystallization being alone wanting to complete the salt under inquiry. For this purpose, the natural combination of it, or pyrites, is first roasted, and then exposed in large heaps under sheds. These heaps are frequently moistened with water, by which, together with the presence of the air, the iron and the sulphur become oxygenated, and crystals of the sulphat begin to form. The water, which is thrown on from time to time, dissolves the salt, and runs into large reservoirs, which are also under sheds, to prevent the rain falling into them. This solution, however, does not contain the salt in a fit state for crystallization, being too highly charged with oxygen. The liquor is transferred into large boilers, and pieces of old iron put into it, which, by taking up the excess of oxygen, change the solution from a red to a green colour. When the evaporation has gone on to a certain point, the salt crystallizes, and the green crystals being separated, are fit for sale.

When the crystals are obtained from a clear solution, and are well defined, exhibiting transparent rhomboidal prisms, the specific gravity of which is 1.8, the salt may be deemed in a state of purity. It dissolves in 2ths its weight of boiling water, and twice its weight of water at 60°. When kept dry, it is not liable to change in the air; but if moistened it becomes covered with red spots by the absorption of oxygen, and if it be dissolved in water, it returns to the state in which it existed before boiling with the metallic iron. When the crystals are heated, the salt at first fuses, then assumes the form of white powder, by losing its water of crystallization. At a red heat the acid begins to fly off; and ultimately a fine red oxyd is left behind. It is in this way the *crocus* of commerce is prepared.

According to the analysis of Bergmann, this salt is composed of

Acid -	39
Protoxyd of iron	23
Water -	38
	100

According to Kirwan:

Acid	26
Oxyd .	28
Water .	46
	100

It is decompofed by the alkalies and alkaline earths; and by all the falts forming infoluble compounds with fulphuric acid.

Oxy-fulphat of Iron.—This falt confifts of the fulphuric acid united to the peroxyd of iron. Its folution in water is of a deep reddifh-brown colour. It is infufceptible of cryftallization. Hence, the green cryftals feparated in making copperas are perfectly diftinct in their nature from the falt which is left in the remaining liquid. When the fulphat is expofed in a ftate of folution for a length of time, it affumes a red colour, and is converted into this falt; fo that we never find the common fulphat in mineral waters, but the oxy-fulphat. This change may be more fpeedily brought about by heating it with nitric acid. A quantity of nitrous gas is evolved, and, according to Mr. Davy, ammonia alfo; the former from the decompofition of the acid, the latter from the decompofition of both the acid and the water. The fluid gradually affumes a deep brown colour. It has a ftrong aftringent tafte, much refembling the juice of floes. When this falt is formed without the addition of water, it is exceedingly heavy, and concentrated, and of a deep brown tint, approaching to blacknefs. If concentrated fulphuric acid be poured into it fuddenly, it lofes its brown colour, and becomes of a clear white, having the confiftence of thick cream. It is fo foluble in water, that when evaporated flowly, inftead of cryftallizing, it affumes the form of fyrup. If too much heat be applied, however, the oxyd either precipitates, or it affumes the form of a fub-falt, and becomes infoluble.

Since the oxy-fulphat differs from the fulphat in the proportion of oxygen only, feveral fubftances reconvert it into that falt, by abftracting the excefs of oxygen. If it be kept, for inftance, for fome time in a clofe-ftopped bottle with iron-filings, the metal becomes oxydized, and the whole is changed to the fimple fulphat.

Gay-Luffac has lately fhewn that the quantity of acid in any metallic falt is in proportion to the quantity of oxygen in the metal. (Memoires d'Arcueil, t. ii p. 159.) Hence no additional acid is required in converting this falt into the fulphat.

Tin, and feveral other metals, produce the fame effect. The excefs of oxygen may inftantly be taken away by paffing fulphuretted hydrogen gas through the oxy-fulphat. This gas reduces the oxyd exactly to a *minimum* of oxydation, to the ftate of protoxyd; and hence the reafon why this gas does not precipitate iron from its folutions.

The oxy-fulphat may be eafily feparated from the fulphat; the former being foluble in alcohol, which the latter is not.

From the method required to form this oxy-falt, it will appear that there are feveral fubftances which may be employed to give their oxygen to the fulphat of iron. Of thefe are the nitric and oxy-muriatic acids. And by pouring a folution of gold into a folution of this fulphat, the oxy-fulphat is produced, and the gold becomes metallic.

Dr. Thomfon enumerates feveral *triple* falts, formed by the fulphuric acid with iron and other metals.

1. Sulphat of iron and copper.
2. Sulphat of iron and zinc.
3. Sulphat of iron and nickel.

The former of thefe fometimes exifts in the blue vitriol of commerce, which is a very great evil to colour-makers. The iron precipitates with the copper, and deftroys the beauty of the latter. In order to afcertain whether iron be prefent in blue vitriol, diffolve a fmall quantity in a wine-glafs, and add aqua ammonia till it fmells ftrong of the latter. The oxyd of copper will be diffolved, and the oxyd of iron left at the bottom. By ftanding for fome time, the precipitate becomes yellow and very confpicuous. It is even faid that fome of thefe falts have triple bafes. The two hitherto obferved are as follows:

1. Sulphat of iron, zinc, and nickel.
2. Sulphat of iron, copper, and nickel.

Sulphite of Iron.—Berthollet has given us an account of a compound of iron with the fulphurous acid. When iron is expofed to the action of this acid, it becomes fpeedily oxydized; but what is fingular, not at the expence of the water, as is the cafe with the fulphuric acid; but it appears that the acid is decompofed, the oxygen uniting with the iron, while the fulphur combines with the falt Hence this fulphat of iron is always contaminated with fulphur. The fulphurous acid has a lefs affinity for iron than the fulphuric; and if the latter be added to the fulphat, its acid is difengaged in the form of gas.

Nitrat of Iron.—The nitric acid has very violent action upon iron, and an abundance of the red fumes of nitric oxyd are difengaged. The fame thing in fome meafure takes place with this acid, as has been remarked with regard to the fulphuric. If it be more than a certain ftrength the action is feeble, until a certain portion of water is added. The fame explanation will anfwer in both inftances. The nitric acid does not diffolve the nitrat at firft formed, the prefence of which interrupts the future progrefs of the operation. When the folution is made with much water the iron is oxydized to a *minimum*, and the falt formed is the proper nitrat. It is of a pale green colour. The veffel in which this folution is made fhould be kept in water as cold as poffible, elfe it will abforb too much oxygen, and pafs to the oxy-nitrat.

Oxy-nitrat of Iron.—When iron is acted upon by the lefs diluted acid, and with heat, the falt formed is the oxy-nitrat. The folution is of a deep brown, refembling the oxy-fulphat. It has a ftrong aftringent tafte, and turns vegetable blues red. When the folution is boiled the oxyd is partially precipitated; nor will it afterwards diffolve in the nitric acid. This has furnifhed one means of feparating iron from other fubftances in the analyfis of minerals.

We are indebted to Vauquelin for a method of obtaining this falt in a cryftallized ftate. The method he recommends, is to keep the black oxyd of iron and ftrong nitric acid together for a length of time, till the cryftals appear. They have an acid tafte, and are deliquefcent. The form of them is that of a four-fided prifm.

The alkalis precipitate the oxyd of iron from this falt of a fine yellow colour, and yield a product which is valuable to painters.

Muriat of Iron.—The muriatic acid, like the fulphuric and nitric, acts feebly upon iron, except it be diluted to a certain extent with water. It differs from the latter, and

agrees with the former, in not being decomposed; but merely takes up the oxyd formed by the oxygen of the water, the hydrogen being given out in the state of gas. The solution is of a green colour; and, on evaporation, it affords crystals presenting the same appearance. Mr. Davy has given us several useful facts relative to this salt. It was employed by him to great advantage in making some eudiometrical experiments. He found that a solution of it absorbs a large quantity of the nitric oxyd gas, which, in this situation, is better fitted for absorbing oxygen than by mixing the two gases together. By absorbing this gas it assumes a brown colour, and acquires an astringent taste. When the compound is heated, it appears that the gas is decomposed as well as a portion of water; since the iron becomes more highly oxydized, and ammonia is formed. Mr. Davy recommends an infallible method of forming this salt, by adding muriatic acid to sulphuret of iron. The sulphuretted hydrogen prevents the muriat from becoming oxy-muriat, which has not the property of absorbing the nitric oxyd. Muriat of iron is very soluble in water and in alcohol. It is decomposed by the alkalis and alkaline earths, and all salts, the bases of which form insoluble compounds with muriatic acid; such as silver and mercury.

Oxy-muriat of Iron.—The muriat of iron, like the sulphat and nitrat, is converted into the oxy-muriat by the oxyd of iron passing from the state of prot-oxyd to that of per-oxyd. It slowly undergoes this change by exposure to the air; and rapidly, by the agency of those bodies which afford oxygen with greater facility, as the nitric and oxy-muriatic acids. The solution is of a deep brown, but does not afford crystals by evaporation. It has a powerful, astringent taste, and a peculiar odour. When this salt is distilled it affords oxy-muriatic acid, leaving in the retort the prot-oxyd of iron.

If the heat be applied rapidly, the salt sublimes; not in the state of oxy-muriat, but of muriat of iron.

There is also a triple salt formed by the muriatic acid with iron and ammonia. This may be prepared by adding iron-filings to muriat of ammonia. It may either be obtained in crystals by evaporation, or it may be sublimed. In the latter state it is known in medicine by the name of *Flores Martis*.

Phosphat of Iron.—The phosphoric acid has little action upon iron; but the acid unites with the prot-oxyd, and forms this compound.

It is prepared by adding a solution of sulphat of iron to a fluid mixture of phosphat of potash. The salt precipitates in the form of a blue powder, which is insoluble in water, and does not lose its colour by exposure to the air.

The substance known by the name of native Prussian blue, is a phosphat of iron; but, what is remarkable, it has little colour when dug out of the earth, becoming deeper on exposure to the atmosphere. A crystallized specimen, lately brought from Brazil, has been analysed by Vauquelin, and is composed of

Acid	21
Protoxyd	45
Water	34
	100

Oxy-phosphat of Iron.—This salt is formed by taking advantage of some oxy-salt of iron and phosphat that is soluble; as, for instance, by adding together the oxy-sulphat, or oxy-muriat of iron, and the phosphat of soda or of potash, a white powder will be precipitated, which is the oxy-phosphat of iron.

This salt is insoluble in water, but dissolves in the muriatic or sulphuric acids; from which it may be precipitated, unchanged, by pure ammonia.

Sub-oxy-phosphat of Iron.—The salt above described is not decomposed by the alkalis like the metallic salts in general. The alkali combines with a portion of the acid only, leaving the salt with an excess of base, which is the sub-oxy-phosphat of iron. This sub-oxy-phosphat does not dissolve in water, or scarcely in acid: but it has the singular property of dissolving in albumen, or the white of eggs: and if an alkali be present, which is the case with the albumen in the serum of blood, it assumes a reddish-brown colour, and is supposed, therefore, to be the principal colouring matter of the red blood of animals.

Fluat of Iron.—The liquid fluoric acid attacks iron, or rather takes its oxyd, which is formed by the oxygen of the water, while hydrogen gas is evolved. It has no striking properties, or any which it may be important to describe.

Borat of Iron.—This salt, being insoluble in water, is obtained by mixing solutions of borat of soda and sulphat of iron together. It appears in the form of a yellowish powder, and melts into glass before the blow-pipe.

If the oxy-sulphat of iron be employed, an oxy-borat will be obtained.

Carbonat of Iron.—When iron-filings are mixed with the liquid carbonic acid, and suffered to remain for some time, the water will acquire a perceptible taste of iron. If it be exposed to the air, a precipitation takes place, either from the gas flying off, or from the salt assuming the state of sub-carbonat. The precipitate is of a yellow colour. This salt is frequently found in mineral waters, to which it gives a peculiar odour. The water, by standing a little while, is not sensible to any of the tests of iron; but a yellow precipitate is found at the bottom of the vessel.

When a solution of neutral carbonat of potash is added to a solution of sulphat of iron, a large quantity of iron is dissolved by the carbonic acid, giving to the fluid a strong inky taste.

This salt is also found native in the solid form, of which we have already spoken in the mineralogical part of this article.

The common rust of iron, formed by exposing iron to the air, may be proved to be a carbonat of this metal by its effervescence with acids. It is, no doubt, from the solubility of this salt, that iron becomes so perishable by exposure to the weather.

The sub carbonat of this species, according to Bergmann, is composed of

24	acid
76	oxyd
100	

It appears from some experiments of Bucholz, that the native carbonat, by heating red-hot, becomes magnetic.

Acetat of Iron.—The acetic acid, when of moderate strength, added to iron-filings, causes the iron to be oxydated by the decomposition of the water, while the hydrogen is set at liberty. The solution has a sweetish, though inky taste, and emits the odour of vinegar. The best way of forming this salt is by mixing acetat of lead and sulphat of iron together. The sulphat of lead becomes insoluble, and the acetat of iron remains in the liquid. Mr. Davy obtained this salt by digesting the sulphuret of iron with acetic acid. It afforded to him crystals in small prisms.

Oxy-acetat of Iron.—If the oxy-sulphat of iron be used instead of the sulphat with the acetat of lead, the sulphat

of lead is precipitated, and an oxy-acetat is held in solution of a beautiful reddish-brown colour. This salt does not afford crystals. It has the smell of vinegar; and, when in solution, affords an excellent test for arsenic. The arsenic forms an insoluble compound with the iron, of a brilliant orange tint. The pyrolignic acid, which is an impure acetic acid, unites with iron, and yields a very cheap acetat of iron, which is used by dyers and calico printers as a mordant.

Succinat of Iron.—When the solutions of succinat of potash or soda, and sulphat of iron are mixed together, a brownish-red insoluble precipitate is formed, which is the succinat of iron. The soluble succinat may hence be employed to separate iron from other substances.

It is composed of

Acid and water	61.5
Oxyd - -	38.5
	100

The *oxalat, tartarat, citrat, malat, benzoat,* and *suberat of iron,* are but little known. They are all, however, soluble in water.

Gallat of Iron.—When the gallic acid is added to any solution of iron, the oxyd being at a *minimum* of oxydation, a fine purple precipitate will be produced. If the acid be entirely freed from tan, the purple colour is much more conspicuous. The pure gallic acid, therefore, is much better as a test for iron, than the mere infusion of galls.

The tan may be separated from this acid by means of gelatine, which does not precipitate the gallic acid. By this treatment a solution may be obtained colourless and limpid.

If the gallic acid be added to a salt of iron, in which the oxygen is at a *maximum*, the precipitate is a very complete black; but the oxyd soon separates, and falls to the bottom in the form of a red powder. This property renders these salts of iron unfit for making writing ink. When the oxyd is in the state of prot oxyd, the combination is permanent; and although it is not so black when first used, it soon becomes dark by exposure to the air. We may hence learn, that while ink is in use, it should not be kept exposed to air; since it passes to the state of oxy-gallat, and the oxyd will fall down.

Prussiat of Iron.—When the triple prussiat of potash and iron is poured into a solution of the latter substance, the oxyd being at a *minimum* of oxydation, a white powder is precipitated, which is the prussiat of iron. If this powder be exposed to the air, it changes to a blue; and in this state is called the oxy-prussiat of iron.

Oxy-prussiat of Iron.—This salt is formed by the same soluble prussiat being added to the oxy-sulphat of iron, and constitutes the beautiful blue pigment, known by the name of *Prussian blue.* It is generally, however, adulterated with alumine. See Prussian Blue and Prussic Acid.

Arseniat of Iron.—The native arseniat has been already described in the mineralogical part of this article. Arseniat of potash, or ammonia, being added to the sulphat of iron, an insoluble powder precipitates, which is the artificial arseniat of iron.

Oxy-arseniat of Iron.—The arseniat of iron, in common with all the other salts of this metal, combines with an extra dose of oxygen, constituting the oxy-arseniat. The precipitate formed by the arsenic acid and the oxy-acetat of iron is of a blueish-white colour.

The oxy-arseniat of iron, from the analysis of Chenevix, is composed of

Acid	42.4
Oxyd	37.2
Water	20.4
	100

Arsenite of Iron.—The arsenious acid, or the common white arsenic of commerce, forms with iron peculiar compounds, which have been but little examined. It does not take the oxyd of iron from the sulphat, but decomposes the acetat, forming with the protoxyd a substance of a greenish-yellow colour; the precipitate from the oxy-acetat being of a bright orange. If either of the acetats contain the least portion of the sulphat of iron, it prevents the precipitation of the arsenite.

Chromat of Iron.—See Chrome.

Most of the other acids combine with iron; but they form compounds which are but little known. Certain alkaline salts act upon iron, and produce triple compounds, which have not received a particular examination. When the nitrat of potash is fused in contact with that metal, the acid is decomposed, and the iron oxydized to a *maximum.* This melted mass, after the acid is completely dissipated, is of a red colour. If, before it becomes deliquescent, which takes place from the presence of the alkali, it be thrown into water, the alkali dissolves a quantity of iron, forming a solution of a deep splendid purple tint. The colour remains permanent for some time, if the air be excluded; but, if exposed in an open vessel, it changes quickly to a green, and the oxyd ultimately precipitates, leaving the liquid clear and colourless. The precipitated oxyd is of a deep red colour.

Description of Plates.

Plate I. *fig.* 1, a plan of an iron forge; *fig.* 2, an elevation of the same. In *fig.* 1. A is a water-wheel, which gives motion to the stamping hammer E; G, the mill-dam; H, the tail water course; I is a small water-wheel, to give motion to the blowing machinery; L, *fig.* 1, is another water-wheel, which works the hammer *o*, for drawing the balls, &c. into bars; K is the mill-dam for supplying all the wheels.

Q, in *fig.* 1, is a refinery, technically called a *finery*; in *fig.* 2. is the elevation. It is blown by the double blowing cylinders, *e, e.* R, the *chafery* for heating the masses of iron a second time after hammering; S, S, plans of balling furnaces, and similar to the puddling furnace.

Plate II. *fig.* 1. is a front view of the finery, as seen *fig.* 2. *Plate* I.; *fig.* 2. being a side view. K, the hearth on which the pig-iron and charcoal is placed; G H, the chimney; *f*, the air-pipe; *g*, a cock to regulate the blast; *h*, a leathern pipe connecting the main-pipe with the nose-pipe; *i*, *fig.* 3, an enlarged view of the tuyere-iron, into which the nose-pipe *i* is inserted, and which enters the hearth at *a*, *fig.* 1.; *m* and *n* are two iron pipes, terminating in, and forming a part of the tuyere-iron. The pipe *m* communicates with a cistern of water, which conveys a stream of cold water, for the purpose of keeping the tuyere-iron cool, and which is discharged at *n*, into the cistern *o*, *fig.* 4, where the whole of this apparatus is seen. The furnace called the *run-out furnace* is very similar to the finery. The hearth of the finery is surrounded with cast-metal plates, having a cavity under the bottom plate, to throw water from time to time to keep the bottom plate cool. The *run-out furnace* differs from this, in being surrounded on three sides with water. This furnace, and its use, has already been described. The chafery is also similar to the

finery, except in the hearth being more like the smith's forge.

Fig. 5. exhibits tongs for taking the balls from the furnace to the hammer; and *fig.* 7. an iron ladle, employed to throw water into the puddling furnace, to oxydate the iron.

Fig. 8. the face of the stamping hammer, which is made to be taken out occasionally.

Fig. 9. the face of the hammer employed for drawing out the bars: *b* is the part used to extend the bars in length with more expedition; the part *a* being employed for smoothening or finishing the bar.

Figs. 10. and 11. are different views of the balling furnace: *a* is the fire-grate; *b*, the hole where the fuel is admitted; *d d*, the roof made of fire-brick; *e*, the door through which the balls are admitted; and *b b*, the hearth on which the balls are laid to be heated, by the flame which is carried by the draught of the chimney G. This furnace is bound on all sides by bars of iron, secured by bolts.

The puddling furnace is so nearly similar to this, as not to require a separate drawing. The hearth is more concave opposite the door, for the purpose of containing the metal which is liquid, previous to its assuming its malleable state. The door of this furnace, for heating the balls, consists of a frame of wrought iron, containing fire-bricks, to prevent the escape of heat. It shuts and opens upon the hole, by being attached to the end of a lever; its weight being counterpoised at the other end. See *fig.* 1. *Plate* IV. where R is the lever; *l*, the door; and *f*, the part by which it is raised.

The door of the puddling furnace consists of a solid piece of cast-iron, about 3 inches thick, having a small hole through it, for the purpose of inspecting the process, and introducing the puddling instruments.

Plate III. *figs.* 1. and 7. are views of the reverberatory furnace, used by the cast-iron founders, for melting large quantities of metal at once. This furnace, like the last, is heated with flame from its fire place *a*, the fuel being introduced at B; *c d* is a sloping hearth, on which the pigs or other pieces of metal are laid; *b*, the door where it is introduced; and *g*, the chimney. The melted metal runs down to the part *o*, where it is accumulated, and is let out at *f*; or a door may be opened at *e* above, and the melted metal carried out in ladles, to be poured into the moulds.

Fig. 2. is a section of a cupola, in which *a* is the interior of the furnace containing the metal and cokes; *e*, the tap hole; *b*, the nose-pipe; *d*, a leathern pipe connecting the air-pipe, which comes from the blowing cylinder, with the same; *e*, a stop-cock to regulate or turn off the blast.

It generally consists of four plates of cast-iron, firmly bolted together; the interior being lined with fire-brick. This furnace is generally employed for the best kind of work, and will melt many charges in a day, according to the nature of the metal exposed in it.

Plate IV *figs.* 1. and 2. are two views of forge-hammer machinery, erected by the celebrated Smeaton. A is the water-wheel; H, a fly-wheel; D, wheel-work to open the shuttle by a little at once, for the purpose of adjusting the quantity of water; F, a cog-wheel to give motion to the wheel G; at the other end, I, are a number of cogs, which lift the hammer K, *fig.* 2, by passing under its shaft, or helve, as it is sometimes termed; L, a large beam of wood inserted into the post M, and passing horizontally over the hammer. Into the posts, M and N, is inserted a piece of ash-timber *o*, against which the hammer K strikes in its ascent, and by its elasticity re-acts upon the hammer, and gives it a greater descending velocity than would be produced by gravity alone. Q is a number of heavy pieces of metal laid upon the beam L, to increase its *vis inertiæ*, and will, in consequence, receive less motion from the hammer. (See MILL-WORK and WATER-WHEEL.) The hammer here described has been much improved, so far as regards the spring at *o*.

That already mentioned in the plate is much preferred. The whole of it is made of cast-iron, and its weight is about 35 *cwt.* It acts simply by its gravity; its extra force, therefore, over the common one, consists in its greater quantity of matter It is made exceedingly massive near the centre of motion, by which means its centre of oscillation is thrown nearer to that point, and it consequently descends with greater velocity. Although this is an advantage with respect to the number of strokes in a given time, it is a disadvantage in another way; since the centre of oscillation is also the centre of percussion, or the point where the greatest stroke is made. Could the velocity be obtained without this evil, the advantage would be material. See TILTING-MILL.

IRON, in the *Materia Medica*, is said to have greater virtues than any of the other metals, which is not to be wondered at, as being the only one that is in a manner soluble in the human body. All the other metals, whether hard or soft, poisonous or salutary, nay even fluid mercury itself, swallowed in their crude state, pass out of the body again unaltered; but this is not the case with iron, its crude filings are often taken as a medicine, and are always so much acted upon by their juices, as to produce considerable effects. It is so easily wrought upon out of the body also by fire, and by different menstruums, that it becomes an aperient or astringent, as it is differently treated; and is, under proper management, greatly superior to all other medicines in chronic cases.

Iron or steel, that is, the *ferrum* or *chalybs*, may be employed indifferently, as Cullen suggests, in the preparation of the rubigo; but he thinks that, upon the whole, the preference is due to the iron in its soft malleable state, or in that which is called "forged iron." As iron, says this medical writer, like all other metals, in its solid and entire state, is not active with regard to our bodies, without being corroded or dissolved by saline matters, he is of opinion, that it is rendered active only by being combined with acids. It has indeed been common to give the entire metal, brought by filing into a fine powder, and with very good effects, as a medicine. But this he does not consider as an exception to his general rule; because he is persuaded that there is constantly present in the human stomach a quantity of acid capable of dissolving iron; and as a proof of it he alleges that he never knew iron given in its metallic or slightly corroded state, without producing a blackness in the stools, which affords a presumption of a previous solution of the iron in acids. As this combination with acids is necessary, physicians and chemists have diversified this combination in a variety of ways; Dr. Cullen observes, that he has not known a preparation of iron for the purpose of medicine, that has not been prepared by combination with acids, or by bringing the iron into a state that rendered it readily soluble by the acid of the stomach, and Dr. Lewis very properly remarks, that Prussian blue, though truly containing a quantity of iron, as it is not soluble in any acid, is the least promising of all the medicinal preparations.

Its virtues internally were not unknown to the ancients; Dioscorides attributes both an astringency and aperiency to it, and prescribes it in hæmorrhages. He also recommends its rust, or *crocus martis*, in suppressions of the menses;

though he, on the other hand, prefcribes wine or water, in which red-hot iron has been quenched, as an aftringent in dyfenteries, diarrhœas, and weakneffes of the ftomach.

Iron combined with acids becomes an aftringent fubftance; and hence its great medicinal virtue is caufed by its tonic and ftrengthening qualities; for by increafing the tone of the veffels, it increafes their vigour and activity. It produces a flight and gentle irritation of the fibres, the effect of which is to conftringe the fenfible organic parts upon which it acts, and to increafe their force and elafticity. Iron particularly acts upon the fibres, and the veffels of the ftomach and inteftines; hence it produces excellent effects in all difeafes which proceed from laxity and inactivity of the digeftive organs. Such are crudities, bad digeftion, accompanied with diarrhœa, flatulencies, flatulent colics, &c. &c. in difeafes which proceed from the former, as many hyfterical, hypochondriacal, melancholic affections, intermittent fevers, tertians and quartans, &c. In thofe cafes iron quickens the circulation and raifes the pulfe; renders the blood more florid, and as it were expands and rarefies the juices, promoting, when they are deficient, and reftraining, when immoderate, the fecretions that are made from the blood, as perfpiration, urine, and the uterine purgations. By the fame corroborating power, which renders it ferviceable in promoting deficient, and reftraining redundant difcharges, where the fuppreffion or flux arifes from debility and relaxation, it increafes, on the contrary, fluxes, and confirms obftructions, when they proceed from tenfion, rigidity, or fpafmodic ftrictures of the veffels. Where either the circulation is quick, or the habit plethoric, by increafing the velocity of the blood, and the plethoric fymptoms, it produces heavinefs, dulnefs, vague heats and flufhings, or kindles more dangerous fevers or inflammations, or burfts fome of the over-diftended fmall veffels. In fome conftitutions, where iron is proper and falutary, particularly in hyfterical and hypochondriacal cafes, and where the ftomach is very weak, it is apt at firft to occafion great ficknefs and perturbation: to remedy thefe inconveniences, Sydenham advifes, to begin with very fmall dofes, and to adminifter it for a while at bed-time, in conjunction with a flight opiate. In other circumftances, it is commonly taken in the morning and afternoon, and moderate exercife ufed to promote its action. In all cafes the dofe fhould be fmall and repeated; a grain, or half a grain of the metal diffolved, or in a foluble ftate, is generally a fufficient dofe. Its effects are known by nidorous eructations, and by the alvine fæces being tinged of a black colour.

Stahl, and feveral other modern chemifts and phyficians, acknowledge only the tonic and ftrengthening qualities of iron. The cafes in which iron has produced a refolving and aperient effect are thofe, in which the obftructions, and the defect of fecretions and excretions, have proceeded from weaknefs and relaxation of the fibres and of the veffels, rather than from a craffitude of humours, as in the chlorofis, in fome kinds of jaundice, and other difeafes of the fame fort.

The fame preparation, as Dr. Lewis has judicioufly obferved, may fometimes exert an aperient, and fometimes an aftringent, power, according to the ftate of the body to which they are applied. *E.g.* If a retention of menfes depends upon a weaknefs in the veffels of the uterus, chalybeate medicines, by invigorating the force of the veffels, may cure the difeafe, and may thereby appear to be aperient; and, on the contrary, in a menorrhagia, when the difeafe depends upon a laxity of the extreme veffels of the uterus, iron exhibited, by reftoring the tone of thefe veffels, may fhew an aftringent operation. However, it is probable, that in the cafes of fuppreffion depending upon a conftriction of the extremities of the veffels of the uterus, the fame tonic powers may not be fo properly employed. By confiderations of this kind, the inutility or propriety of the medicinal preparations of iron may be determined. In all cafes of active hemorrhagy they muft be hurtful; and in cafes of hemorrhagy from external violence, Dr. Cullen would judge them to be ufelefs, if not hurtful. In cafes of a general flaccidity, as it is frequently marked under the title of "Cachexy," and in all cafes of evacuations from laxity, whether fanguine or ferous, they are likely to be the moft effectual remedies. The good effects of the preparations of iron, as Dr. Cullen apprehends, have been often miffed by their being given in too fmall dofes. The faline preparations, in large dofes, are ready to irritate the ftomach; and for this reafon, and fome others, it muft be always proper to begin with fmall dofes, and to increafe them by degrees; but he has often found, that no great benefit is to be obtained but when large quantities, either by the fize of the dofes, or by the long continuance of them, have been thrown in. He fays, that he has found the fimple ruft as effectual as any other preparation, and the ftomach has borne it better than any other. He begins with a dofe of five grains, but gradually increafes it to what the ftomach eafily bears. Some are faid to have given it to the quantity of fix drams in one day; but he has hardly found any ftomach that would bear the third part of that quantity without much ficknefs. He thinks that the ftomach bears it better by joining with it fome aromatic.

The preparations of iron that have been in more frequent ufe, and fome of which are at prefent continued under different names, are, 1. The crude filings reduced to an impalpable powder; this is an excellent form for adminiftering iron in female diforders, in which the body is weak, languid, and full of acidities; the dofe of the filings is from two or three grains to a fcruple or more. 2. "Mars faccharatus," which is the filings candied with fugar, by diffolving two parts of fine fugar in water, and boiling it down to a candy confiftence, and adding, by little and little, one part of the cleanfed filings in a kettle over a gentle fire; the veffel being continually fhaken, that the filings may be crufted over with the fugar. In order to prevent the mixture from running into lumps, a little ftarch is previoufly mixed with the fugar, in the proportion of a dram to a pound. 3. "Limatura Martis præparata," or "Chalybis rubigo præparata," is formed by moiftening the filings with vinegar or water, and expofing them to a moift air, or occafionally moiftening them afrefh, which foon change in great part into ruft; this ruft may be feparated from the uncorroded part, by grinding and wafhing over the fine powder with water. This is given in the fame dofe as the crude filings.

This preparation, which was denominated "chalybis rubigo præparata" in the London Pharmacopeia of 1745, and "ferri rubigo" in that of 1787, is now called "ferri carbonas," or carbonate of iron. It is formed of fulphate of iron, eight ounces; fub-carbonate of foda, ten ounces; and a gallon of boiling water. Diffolve the fulphate of iron and fub-carbonate of foda feparately, each in four pints of water; then mix the folutions together, and fet by the mixture, that the precipitated powder may fubfide; having poured off the fupernatant liquor, wafh the carbonate of iron with hot water, and dry it upon bibulous paper in a gentle heat.

There are two oxyds of iron, both of which are combined with acids, and form different modifications of the fame falt, a diftinction that ought to be particularly regarded

in medicine; they have been named, from their colour, black and red oxyds; the former, which is black, or (if formed as in the present instance, by precipitation from water) greenifh, confifts of iron 73, and oxygen 27, according to Lavoifier. It may be formed in various ways: as by expofure of a pafte of iron-filings and water to the air; by heating together one part of red oxyd of iron, and two parts of iron-filings; and by adding a folution of alkali to one of green fulphate of iron, and drying the precipitate quickly without expofure to air; and it is kept as a feparate article in the Edinburgh Pharmacopeia, under the name of "Ferri oxydum nigrum purificatum." The latter, or red oxyd, confifts, according to Prouft, of iron 52, oxygen 48, and in its relation to black oxyd is compofed of 66.5 of that oxyd, and 33.5 of additional oxygen. Some chemifts have fuppofed the exiftence of other gradations of combination of iron and oxygen, but the above are all that are generally admitted, or that require particular notice; this latter is alfo kept in the Edinb. Pharmac. under the name of "oxydum ferri rubrum." Salts containing the black oxyd, on expofure to air, pafs to the ftate of red oxyd, by attracting oxygen from it, and in the procefs of drying, the fame change happens here to the oxyd in the fub-carbonate, which, at the time of its firft precipitation, is a black oxyd. The fame fubftance, more imperfectly prepared, conftituted the ruft of iron (*ferri rubigo*) of the former Pharmacopeia, for which, in all the proceffes into which it entered, this precipitate is now fubftituted. The red oxyd of the Edinburgh college is the old "Colcothar vitrioli," and formed by expofure of common fulphate of iron to a ftrong heat, fufficient to drive over its fulphuric acid, when the red oxyd remains behind, as in the procefs which was formerly in ufe for obtaining that acid. Sub-carbonate of foda is preferred for the precipitation to that of potafh, on account of the greater folubility of the fulphate of the former than of the latter alkali, and the confequent facility with which it may be wafhed away. The falt is a fub-carbonate, but as only one of the compounds is kept, the relation is not expreffed. The dofe of the "ferri carbonas" is from two to ten grains.

4 "Mars fulphuratus," prepared by mixing iron-filings with twice their weight of flower of brimftone, and as much water as will make them into a pafte, which in a few hours fwell up, and is then pulverized, and put into a heated crucible to deflagrate, and kept conftantly ftirring with an iron fpatula, till it falls into a deep black powder: this powder urged longer in the fire, becomes red, and is called, 5. "Crocus martis aperiens et aftringens." 6. The falt or vitriol of iron, "ferrum vitriolatum," called "Sal martis." This is now difufed. See Crocus *Martis*.

This is the "ferri fulphas," fulphate of iron, of the Lond. Pharm. of 1809; and is compofed of iron and fulphuric acid, of each by weight eight ounces, and four pints of water. The fulphuric acid and water are mixed together in a glafs veffel, and the iron is added: then, after the effervefcence has ceafed, the folution is filtered through paper, and evaporated, fo that cryftals may form as it cools. The water is afterwards poured away, and the cryftals are dried upon bibulous paper. Upon a large fcale this falt is formed from native fulphuret of iron (*pyrites*) by moiftening, and expofing it to the open air. The fulphate of iron is afterwards diffolved in water and cryftallized by evaporation. Sulphuric acid will unite either with the black or red oxyd: the firft of thefe is the falt here intended for internal ufe, and upon this point great ftrefs ought to be laid; as the laft is the ftate in which the fulphate of trade is ufually found, and which, for medical purpofes, is a very diftinct and inferior thing. Its cryftals are tranfparent rhomboidal prifms, of a light green colour; its tafte is aftringent and ftrong, and it reddens vegetable blues. One part is foluble in two of cold, and in three-fourths of boiling water. It is infoluble in alcohol, in which menftruum the red fulphate is foluble, and this affords a method of afcertaining the exiftence of the latter with the former, as alfo of feparating it. On expofure to air it is gradually converted into red fulphate: it confifts, according to Kirwan, of acid 26, iron 28, and water 46, parts. Heat drives off the water of cryftallization, and the falt remains white: if urged farther, it drives over the acid, and leaves firft a red fulphate, and at laft a red oxyd of iron. The dofe of the "ferri fulphas" is from one to five grains. 7. "Tinctura martis in fpiritu falis," P. L. 1745, "Tinctura ferri muriate," P. L. 1787, or "Tinctura ferri muriati," tincture of muriate of iron, P. L. 1809. This is formed by pouring the muriatic acid, in the proportion of a pint, upon half a pound of carbonate of iron in a glafs veffel, and fhaking it occafionally for three days; then fetting it by, that the fæces, if there be any, may fubfide; pouring off the folution, and adding three pints of rectified fpirit. This falt appears to be an oxymuriate of iron, the red oxyd of iron employed becoming, on its combination with the acid, black oxyd, and giving over its fuperabundant oxygen to the muriatic acid. This appears to be its ftate, becaufe fulphuric acid added to it detaches oxymuriatic acid, and heat drives over oxymuriatic acid; and in the latter inftance, although the red oxyd was ufed for its preparation, the black oxyd remains behind. The falt, evaporated to drynefs, yields an orange-coloured mafs, which is uncryftallizable, deliquefces on expofure to air, and is foluble in alcohol. The tincture has a brownifh yellow colour, and very aftringent tafte. 8. "Flores martiales," P. L. 1745, flowers of iron (fee Flores), "Ens Veneris," P. L. 1720, "ferrum ammoniacale," P. L. 1787, or "ferrum ammoniatum," ammoniated iron, P. L. 1809, is compofed by intimately mixing carbonate of iron and muriate of ammonia, of each a pound, and fubliming by immediate expofure to a ftrong fire, and, laftly, reducing the fublimed ammoniacal iron to powder. This fubftance confifts of red muriate of iron, mixed by fublimation with muriate of ammonia. It is orange-coloured, with a fmell refembling faffron, is deliquefcent, and foluble in alcohol. The refidue, which is deliquefcent, confifts alfo of red muriate of iron, and was formerly kept under the name of "lixivium martis." The dofe is from three to fifteen grains. 9. "Tinctura florum martialium," P. L. 1745, "Tinctura martis Mynfichti," P. L. 1720, "Tinctura ferri ammoniacalis," P. L. 1787, or "Tinctura ferri ammoniati," tincture of ammoniated iron, P. L. 1809, is formed by digefting four ounces of ammoniated iron in a pint of proof fpirit, and then ftraining. This is an elegant chalybeate, and may be given in dofes of a teafpoonful. 10. "Ferrum tartarizatum," or tartarized iron, P. L. 1787 and 1809, called alfo "Mars folubilis," and "Chalybs tartarizatus," confifts of iron, a pound, fupertartrate of potafs, powdered, two pounds, and a pint of water. Rub them together, and expofe them to the air in a broad glafs veffel for eight days, then dry the refidue in a fand bath, and reduce it to a very fine powder. Add to this powder a pint more of water, and expofe it for eight days longer; then dry it, and reduce it to a very fine powder. This is a triple falt, in which the iron is firft oxydated by being moiftened and expofed to air, and then combines with the fuperabundant acid of the fupertartate of potafs; and it is therefore a tartrate of potafs and iron. It may be diffolved in water and cryftallized. This elegant and ufeful chalybeate may be given either in a folid or liquid form, from five

grains to a fcruple. It has been ufually diftinguifhed in the fhops by the name of its inventor, Dr. Willis. 11. "Liquor ferri alkalini," or folution of alkaline iron, is compofed of $2\frac{1}{4}$ drams of iron, two fluid-ounces of nitric acid, fix fluid-ounces of diftilled water, and fix fluid-ounces of the folution of fubcarbonate of potafs. Having mixed the acid and water, pour them upon the iron, and when the effervefcence has ceafed, pour off the clear acid folution; add this gradually, and at intervals, to the folution of fubcarbonate of potafs, occafionally fhaking it, until it has affumed a deep brown red colour, and no farther effervefcence takes place. Laftly, fet it by for fix hours, and pour off the clear folution. This preparation was firft defcribed by Stahl, and called "tinctura martis alkalina," and it is for the firft time introduced into the London Phamacopeia of 1809, as affording a combination of iron diftinct from any other, and often applicable to practice. It feems to be a triple falt, formed by the union of nitric acid with red oxyd of iron, and with potafs. Dr. Lewis has obferved, that alkaline folutions of iron are ill adapted for medicinal ufe; and on that account, he fays, they have been wholly neglected in modern practice. 12. "Vinum ferri," wine of iron, P. L. 1787 and 1809, "Vinum chalybeatum," P. L. 1745, confifts of two ounces of iron-filings mixed in two pints of wine. The mixture is fet by for a month, occafionally fhaking it, and it is then filtered through paper. Lewis Mat. Med. Cullen Mat. Med. London Pharmac. 1809. See *Chemical Properties of* IRON, *Chalybeates*, and *Mineral*, &c. WATERS.

IRON, *Cafe-hardening of*, a procefs by which a fuperficial hardnefs is given to various articles made of iron. It is found by experience that pure iron is not fufceptible of a very fine polifh, and that, when it is expofed to the air, it very foon changes. All iron utenfils, therefore, fuch as fire irons, and many other articles, having the appearance of polifhed fteel, are cafe-hardened, for the purpofe of giving them a finer polifh, as well as rendering their colour more permanent. The goods to be cafe-hardened fhould be finifhed with the exception of polifhing, fince, if the procefs be well managed, the moft delicate workmanfhip will not be injured. A box of wrought iron muft be provided, which is perfectly found in every part, having a lid of the fame metal, to fit very tight. In this box the articles are to be ftratified with powdered carbon, that of animal fubftances being the beft, for reafons given in the article IRON, in the fection on *Steel*. The box being perfectly filled with thefe materials, let the lid be fitted on, and luted all round with a pafte made of equal parts of pipe-clay and Calais fand. The whole is now to be furrounded by bricks loofely built up, a little higher than the top of the box, leaving about four inches on each fide for fuel. This may be done either upon a fmith's hearth or in the open air. The moft proper fuel is the refufe-cokes from any fires where pit-coal is burnt. The fire being kindled, and the fpace filled up with this fuel, the heat will be applied gradually, owing to the fmothered combuftion. As foon as the box appears of a light red heat, let it remain about half an hour, or more time if the box be large, in the fame temperature. The lid may now be taken off, and the box inverted and its contents emptied over a ciftern of cold water. If the box be fuffered to cool without being opened, the goods will be perfectly white and metallic when taken out. If they are now heated red-hot, and quenched in cold water, they acquire the fame hardnefs as if turned out of the box red-hot into the water. If the articles are very delicate, fo as to be injured by the air in heating a fecond time, they may be preferved, by dipping them into a mixture of a faturated folution of falt (muriate of foda) with any vegetable matter to give it a pulpy confiftence. During the time of heating it red-hot, the falt fufes upon the furface of the metal, defending it from the oxygen, fo that after it is quenched in the water, and brufhed, it will be perfectly clean.

The fize of the iron box fhould not be very large; it is better to do the work at two or three proceffes. Charcoal is a very bad conductor of heat, and if the mafs to be heated were large, thofe articles near the fides would be over done, by combining with too much carbon, while thofe in the middle would be too little carbonated.

People in the habit of cafe-hardening, have generally fome fecret receipt for the procefs, on which they fet great value. All, however, agree in ufing carbon, the only thing neceffary: fome add to this falt-petre; others fal ammoniac, and other articles, to which they very knowingly attribute their relative fuccefs. We can, however, affure the moft fage of thefe perfons, that if they make their box perfectly air-tight, by the rules above given, ftratifying the articles with animal carbon alone, they will, with proper heat and time, produce the greateft poffible effect.

Animal carbon may be produced from moft animal fubftances: among thefe are blood, hoofs, and leather. Thefe fubftances fhould be preffed into an iron pot, which can be heated red-hot, covered clofe, with a fmall open tube inferted into the cover. The volatile matter that efcapes may be fet on fire, which will in a great meafure deftroy the fmell; or a receiver may be adapted, and the crude ammonia diftilled off. When the volatile fubftances have come over, the refiduum will be fine animal carbon, which requires only to be reduced to powder.

This animal carbon is fo fitted for combining with iron, that if it be made into a pulp with a faturated folution of falt, and laid upon the furface of iron; upon being heated red-hot, and quenched in cold water with this coating upon it, the furface will become hard. Any part of an iron article, not wifhed to be *cafe-hardened*, may be prevented from undergoing the change, by covering the part with pipe-clay.

IRON, *For the blueing of*, fee BLUEING.

IRON, *For the expanfion of, by heat*, fee HEAT and PYROMETER.

IRON *Chambers*. See CHAMBERS.

IRON, *For the refining of*. See REFINING and IRON, § 4. *fupra*.

IRON, *For the converfion of, into fteel*. See IRON and STEEL.

IRON *Furnace*. See BLAST-*Furnace*, and IRON, *fupra*.

IRON, *Harping*. See HARPING.

IRON-*liquor*, in *Calico Printing* and *Dyeing*, is a folution of iron in the acetic acid, ufed as a mordant for certain colours. It is employed as a fubftitute for the fulphat of iron, and is preferred, in thofe proceffes, to the laft falt. The oxyd of iron, which is the effential ingredient, is more eafily attracted by the ftuff from the acetic than the fulphuric acid, and, befides, the texture is not fo liable to be injured by the acetat as the fulphat of iron. In order to make this fubftance cheap, the acid diftilled from wood, called pyrolignic acid, and now found to be impure acetic acid, is ufed as a fubftitute for vinegar. See PYROLIGNIC *Acid*, and the laft fection of the article IRON.

IRON-*moulds* are marks or ftains produced on fubftances, particularly linen and cotton, by the oxyd of iron. The affinity of thefe vegetable fubftances for the oxyd of iron is fo great, as not only to take it from the furface of iron, but from any acid with which it may be combined. We find, hence, that very few acids are capable of removing iron-moulds. From the well-known fact that the attraction of acids for oxyds of metals is more feeble as the latter contain

more oxygen, we are enabled to account for iron-moulds being easier to remove, as they are more recent. The stain soon acquires an orange-red colour, by absorbing oxygen, and is with more difficulty extracted. Various means are employed by the laundresses for removing stains of iron, the most general of which is the citric acid, commonly called salt of lemons. The muriatic acid is frequently employed by the bleachers, and it is by far the most rapid and effectual process; but the great caution necessary, in suddenly washing the spot after the stain has disappeared, lessens its utility for domestic use. When the spot is dipped into the clear muriatic acid, the iron almost instantly disappears, and it is at that instant the part should be plunged into a quantity of clean water, and washed as quick as possible; the washing being continued for a considerable time.

In order to render the oxyd of iron more easily soluble by any acid, let the part stained be steeped for some time in a solution of sulphuret of potash, or, what is more easily obtained, sulphuret of lime, rinsing it afterwards in clean water. The oxyd will be deprived of some of its oxygen, and may be removed by almost any acid, when it is so dilute, even, as not to injure the stuff, however long it may remain in it.

It may be proper here to observe, that the tartaric and oxalic acids remove iron-moulds equally well with the citric acid.

When the substance iron-moulded is printed calico, and of a buff colour, or any other colour in which iron is employed as a mordant; it will be found that, in removing the iron-mould, the proper colour will also disappear. In this case there is no effectual remedy.

Most of the iron-moulds are produced in the washing, for want of sufficient caution. In those utensils in which metal is at all necessary, copper or zinc should be employed instead of iron. With care, however, iron vessels may be safely used. When they are not in use, the surface of the iron should, after being made clean and dry, be smeared over with oil or tallow, and rubbed dry at the time they are used.

Iron-*moulds*, yellow lumps of earth or stone, found in chalk-pits about the Chiltern, in Oxfordshire, and elsewhere, being in reality a kind of pyrites, or indigested iron-ore.

Iron-*shot*, in *Mineralogy*, is a term applied by Mr. Jameson (Geognos. vol. iii. p. 47. 159.) to such rocks and stones as are coloured or clouded by the oxyds of iron. Ferruginous is a more common name for this very common appearance in the strata.

Iron-*sick*, a *Nautical Term*, signifying the decay of the iron fastenings by its corrosion with the sea water, by which the continuity of the parts is gnawed away by degrees, whereby the vessel is not only rendered weak, but leaky.

Iron-*stone*, is that species of iron ore which abounds with a considerable proportion of earth, such as lime, or alumine, and is the ore most common in this country. See Iron.

The manner of getting iron-stone is divided into three departments: 1. By *stall-work*: 2. By *bell-pits*: and 3. By *open-work*. The first of these methods is employed when the stone lies at a considerable depth. After sinking a shaft to the lower part of the stratum, the ground is excavated in an horizontal direction, leaving at intervals certain parts standing to support the roof of the excavation. The spaces between these pillars are called *stalls*.

The *bell-pit* is employed when the iron-stone lies at some distance from the surface, and where the ground is not sufficiently firm to admit of stall-work. These pits, when first opened, are narrow, but become wider below, assuming the shape of a bell.

The third method, or the *open-work*, is made use of when the stratum containing the stone is nearly bassetting, or is very near to the surface. The earth is first removed, laying the stratum containing the ore bare, and the stone is got out as from an open quarry.

The argillaceous iron ores are generally called iron-stones, and abound in many of the coal districts. In Mr. Farey's Agricultural and Mineral Report on Derbyshire, vol. i. p. 217, a list of seventy-five places in and near that county is given, where iron-stone has been dug, or where the rakes of iron-stone, as they are there called, have been worked.

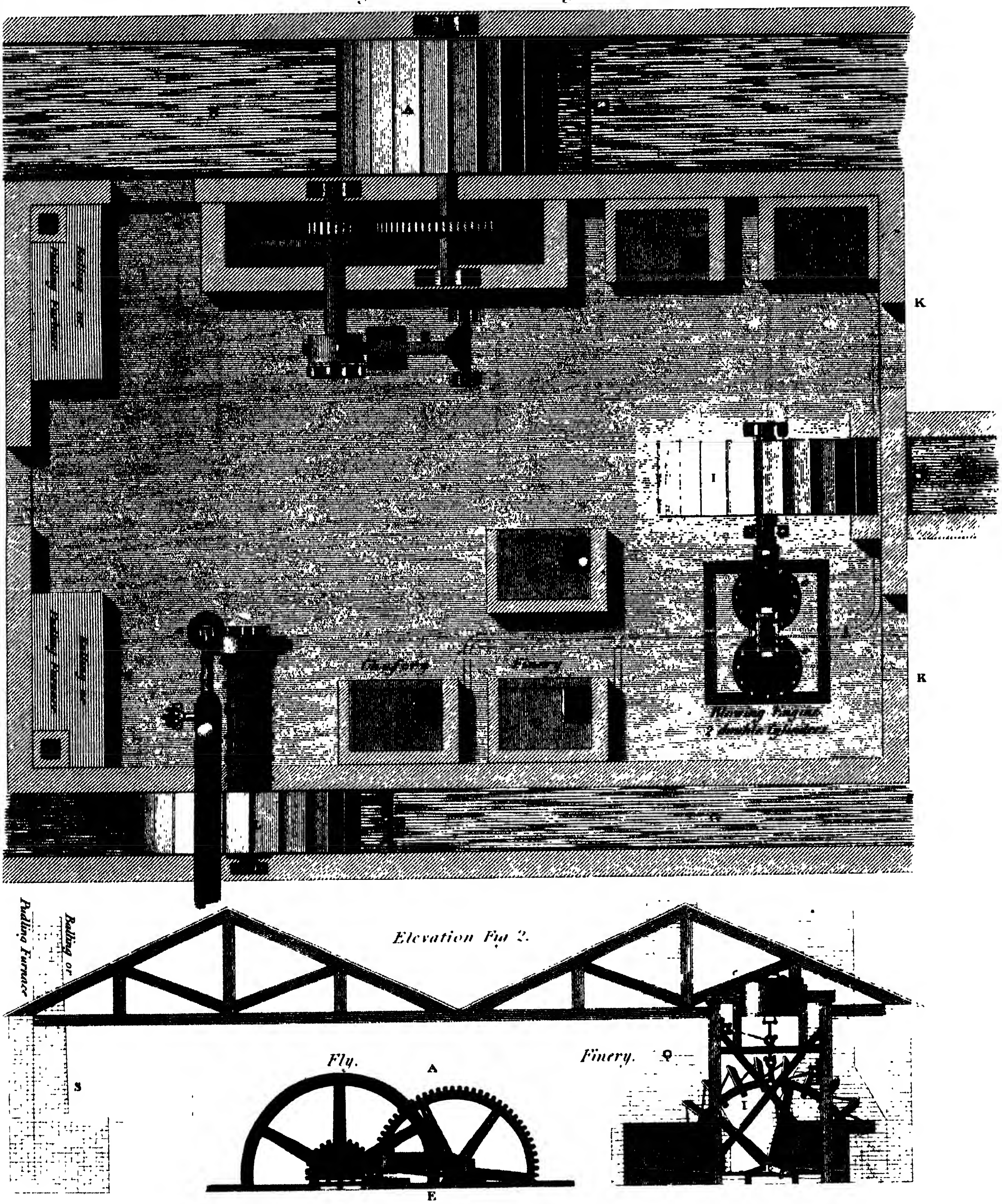
Iron-*wood*, in *Botany*. See Sideroxylon.

Iron-*work*, in a *Ship*, denotes all the pieces of iron, of whatsoever figure or size, which are used in its construction; as bolts, boom-irons, which are composed of two rings, nearly resembling the figure of 8, nails, spikes, chains, and chain plates, block-strops, cranks, braces, pintles, and goodgings.

Iron-*works*, a name given to the establishments for the manufacture of pig-iron. (See Blast-*furnace* and Iron.) The most proper situation for iron-works is on the side of a hill, from which a perpendicular descent could be formed nearly equal to the height of the blast-furnace. The upper ground by this means is on a level with the mouth of the furnace, where all the materials are introduced, and is therefore the situation where the ore is roasted, and the cokes prepared; the lower ground being the most proper for the rest of the works.

Where such local advantages do not exist, the materials are drawn up on an artificial inclined plane, by appropriate machinery.

Fig. 1. Plan of an Iron Forge.



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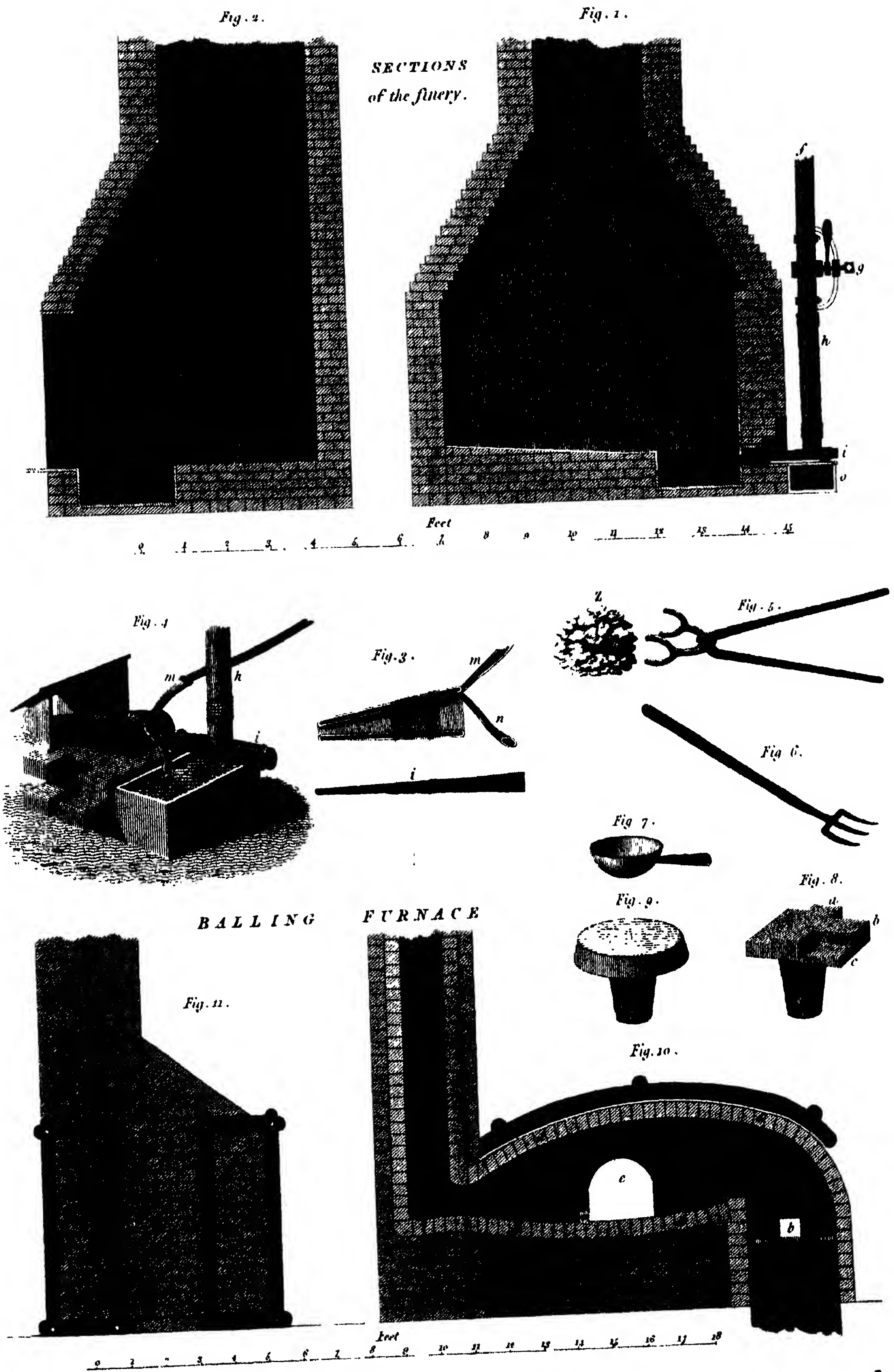
IRON MANUFACTURE.



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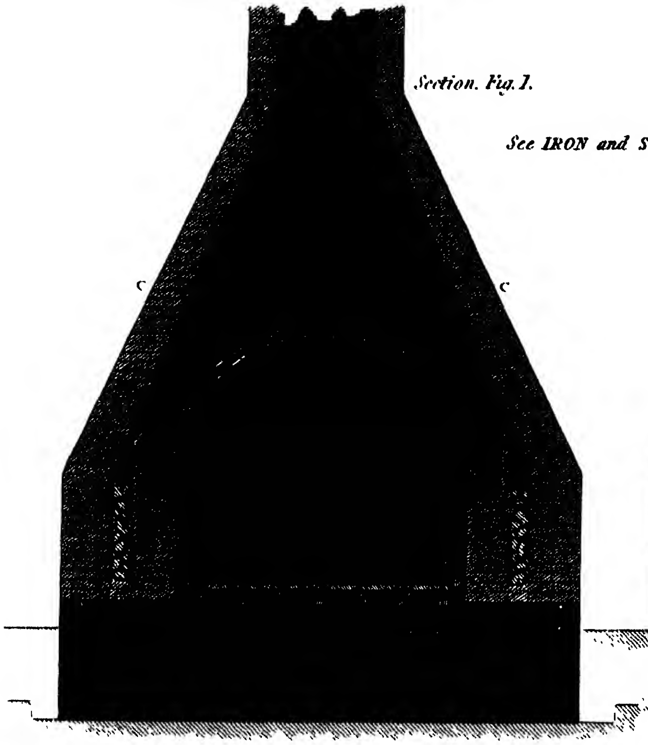
J. Farey delin.

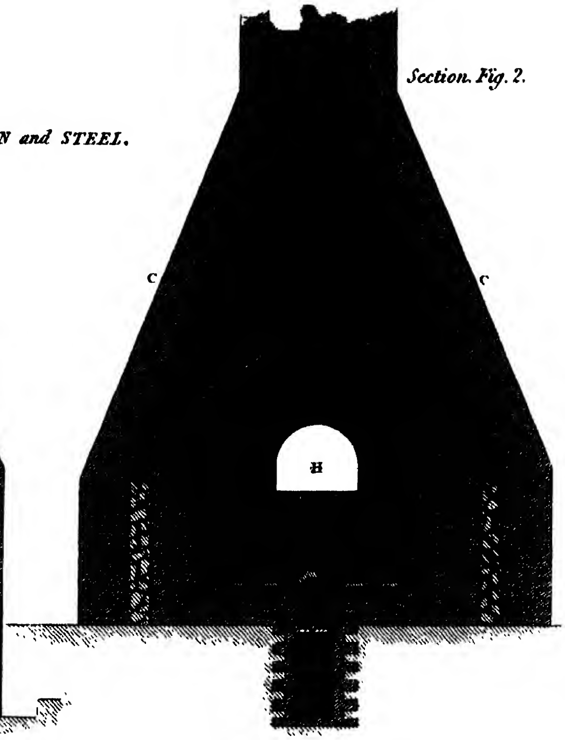
IRON MANUFACTURE.

STEEL CONVERTING FURNACE.



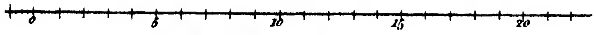
Section. Fig. 1.

See IRON and STEEL.



Section. Fig. 2.

Scale of Feet.



Plan. Fig. 3.

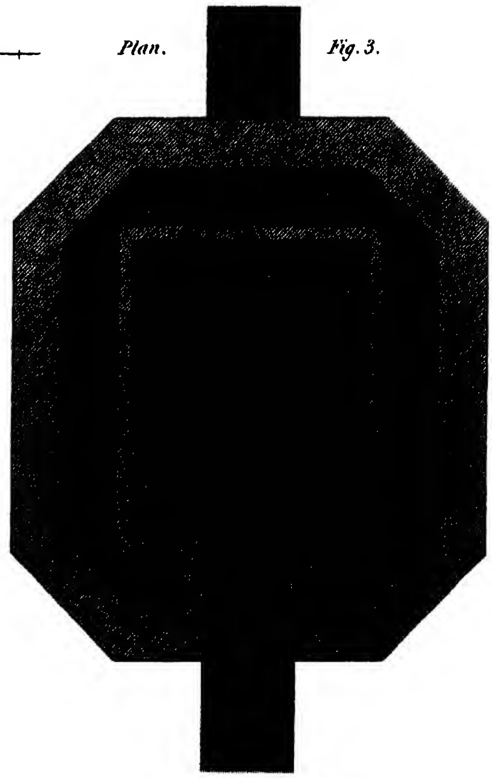


Fig. 4.

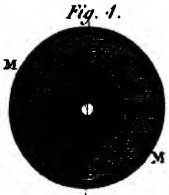


Fig. 7.

Fig. 6.

Mould for making Crucibles.

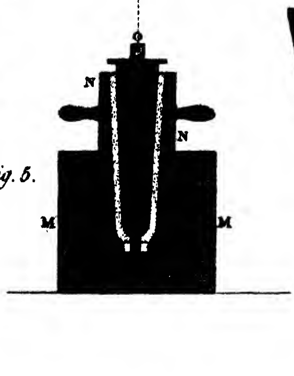


Fig. 5.

Published as the Act directs, [illegible], by Longman Hurst, Rees, Orme, and Brown, Paternoster Row.

Lowry sculp.

Mr. Smeatons design for the Machinery of the Hammer at Kilnhurst Forge.

Fig. 1. Elevation in Front.

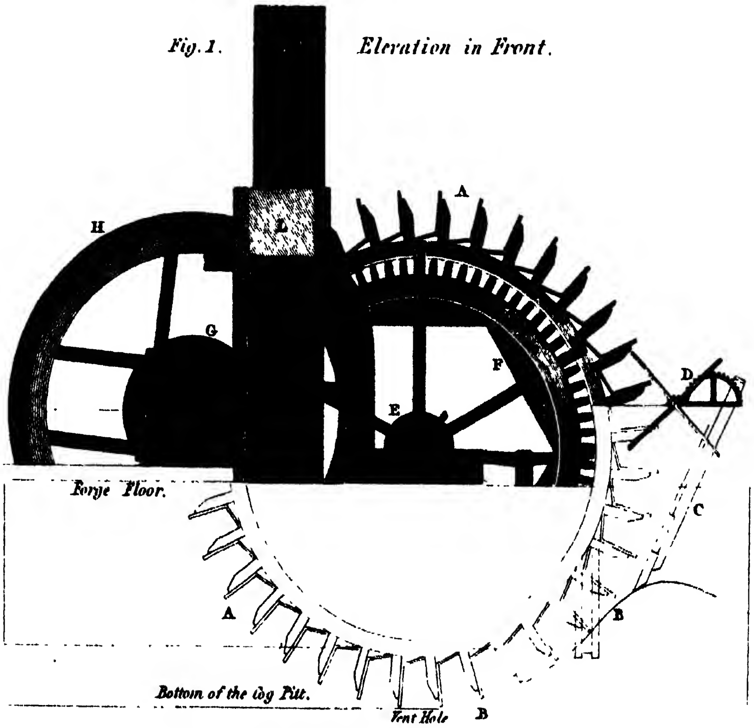
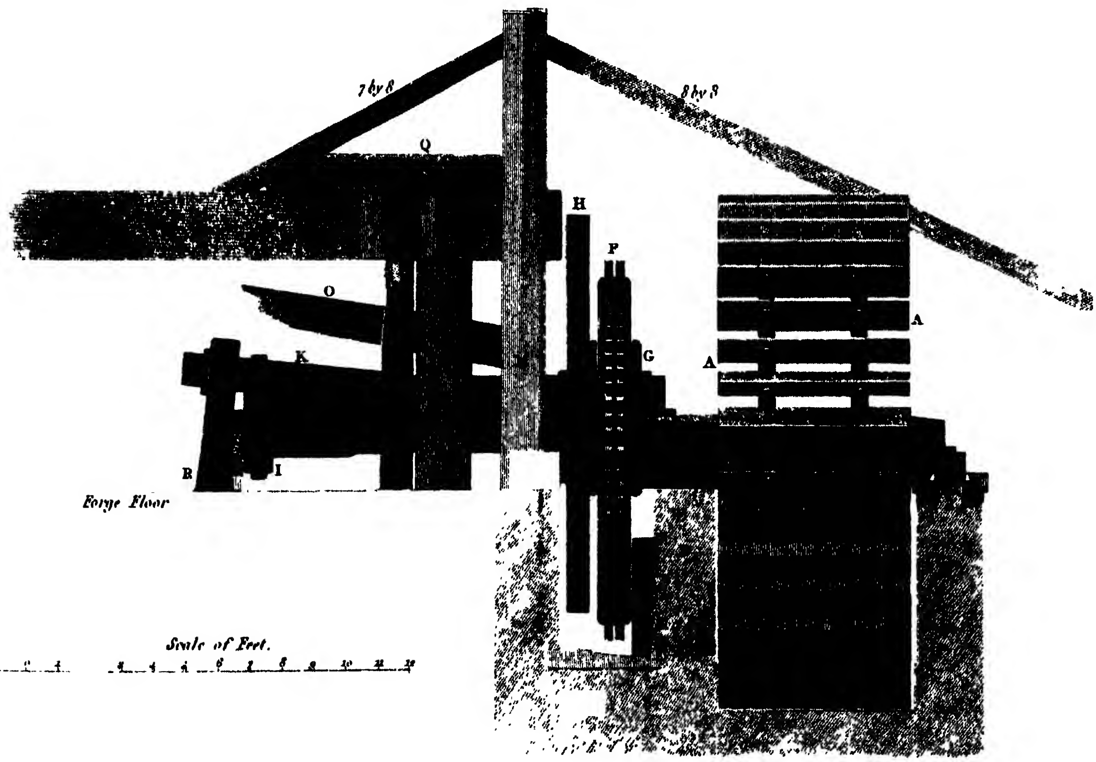


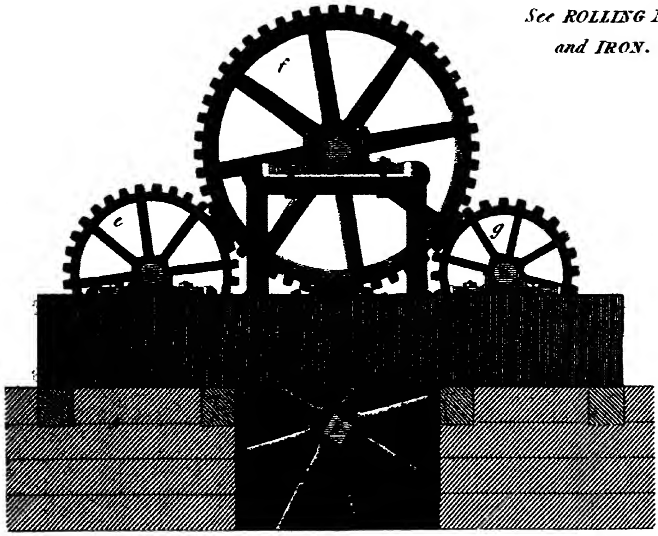
Fig. 2. Elevation Sideways.



J. Farey Junr. delin. Published as the Act directs, 1811, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row. Engraved by Wilson Lowry.

See ROLLING MILL and IRON.

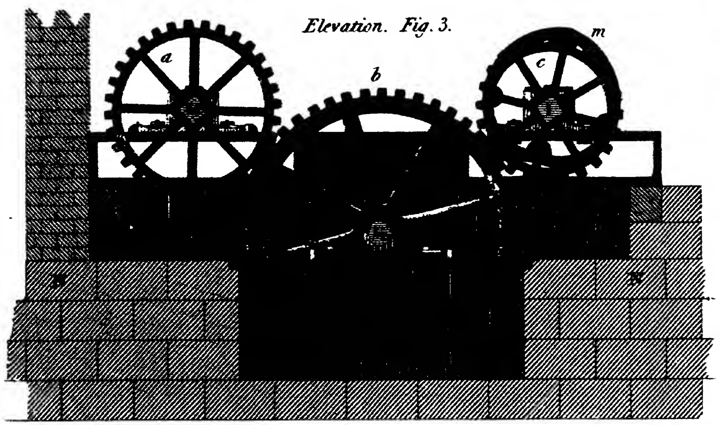
Elevation. Fig. 2.

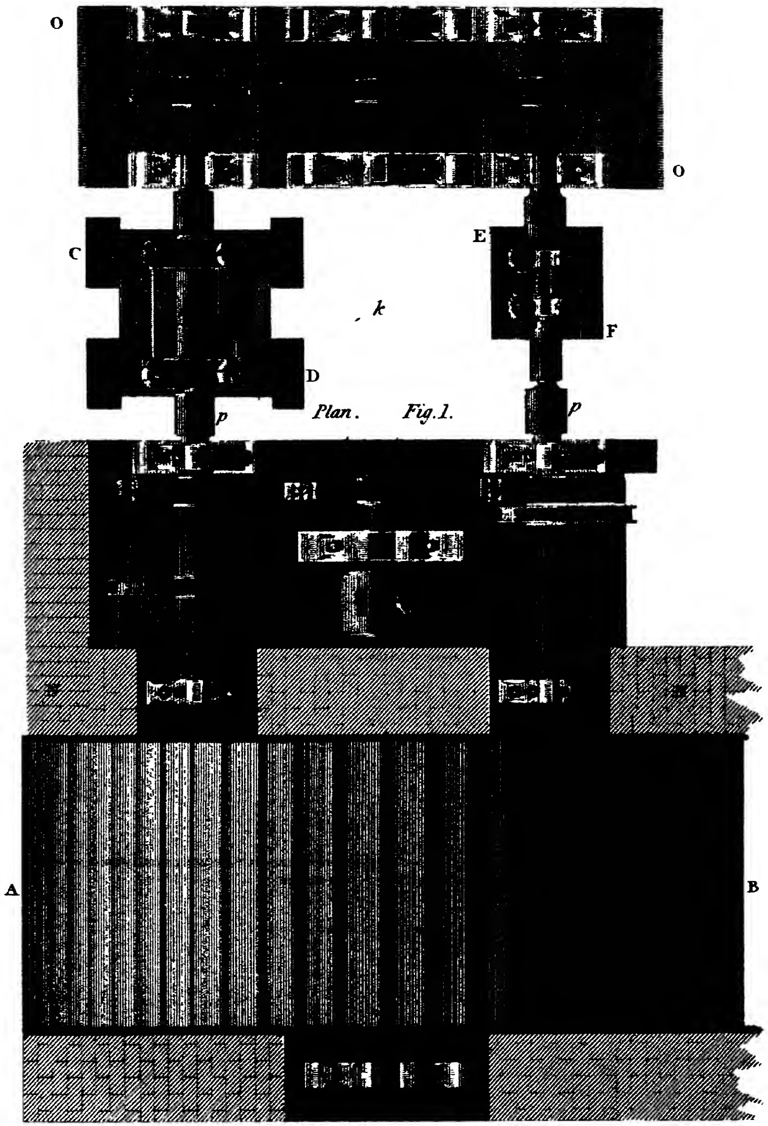


Scale of Feet.

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Elevation. Fig. 3.





Plan. Fig. 1.

Farey del.

Published as the Act directs 1812 by Longman Hurst Rees Orme and Brown Paternoster Row London

Lowry sculp.

ROLLERS for making BAR IRON.

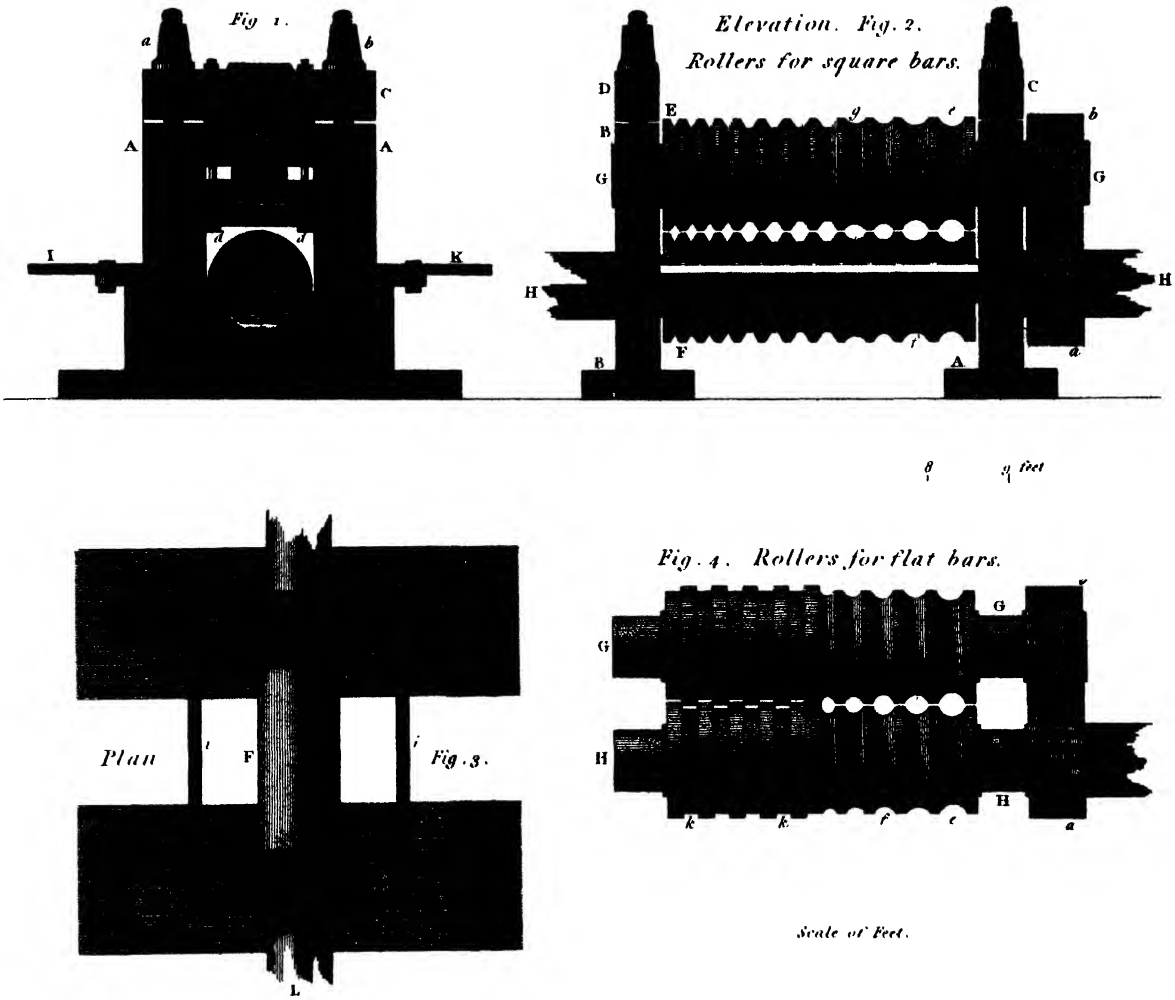
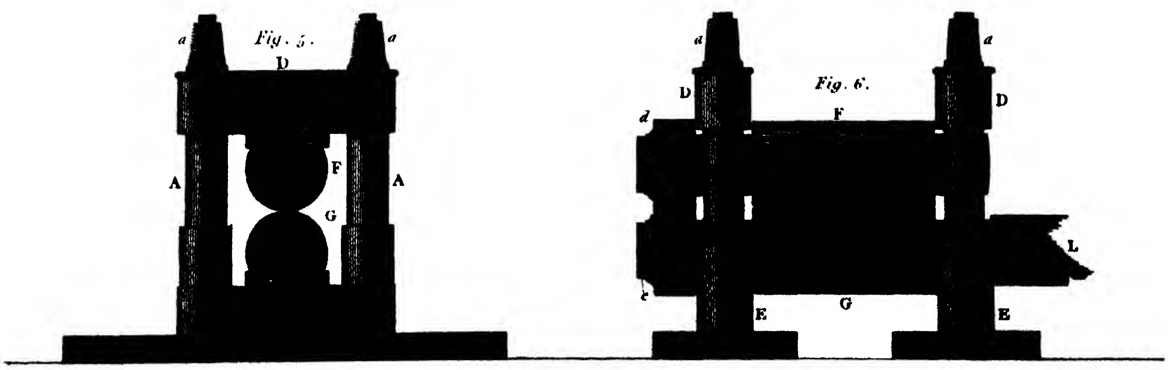


Plate Roller.

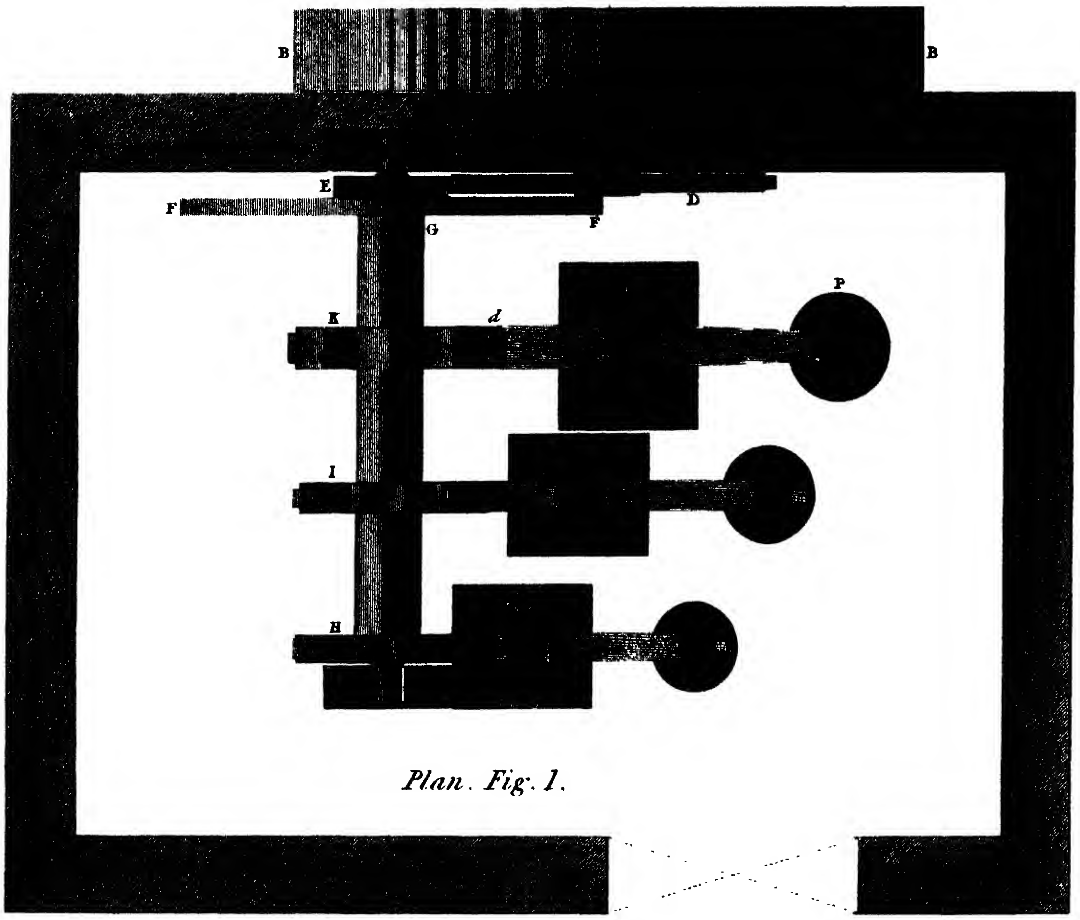


J. Farey delin. *Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.* *Engraved by W. L.*

IRON MANUFACTURE

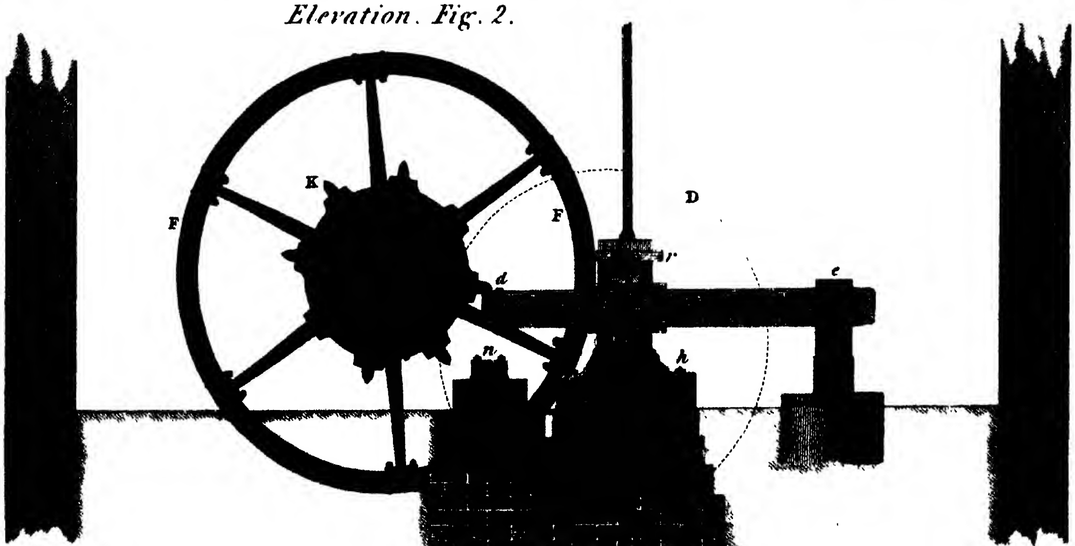
MILL FOR TILTING STEEL,

by Mr. Smeaton.



Plan. Fig. 1.

Elevation. Fig. 2.



Farey delin.

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Engraved by W. Lowry.

Kaolin

KAOLIN, the name of one of the two ſubſtances which are the ingredients of china-ware. The other, which is called *petuntſe*, is eaſily vitrifiable, and this kaolin is ſcarce at all ſo: whence the fire compoſes from a mixture of them both a ſemi-vitrification, which is china-ware. See PORCELAIN.

The kaolin, uſed in the compoſition of porcelain, requires leſs labour than the petuntſe. There are large mines of it in the boſoms of certain mountains, the exterior ſtrata of which conſiſt of a kind of red earth. Theſe mines are very deep, and the kaolin is found in ſmall lumps, that are formed into bricks, after having undergone the ſame proceſs with the *petuntſe;* which ſee. Father d'Entrecolles thinks that the earth called terre de Malte, or St. Paul's earth, has much affinity to the kaolin, although it has not thoſe ſmall ſhining particles which are interſperſed in the latter.

M. Reaumur had an opportunity of examining this ſubſtance, not in its native ſtate, but only in form of ſmall bricks, made out of the paſte of the powder of the native kaolin and water. He found it of a white colour, and ſprinkled all over with fine glittering particles; but theſe he did not judge to be fragments of a different ſubſtance mixed among the maſs, as are the ſmall flakes of talc in our clays and ſands; but that the whole maſs was compoſed of ſome ſtone reduced to powder, and made into a paſte with water, and that theſe larger ſpangles were only coarſer particles of the powder; the examination of which he promiſed himſelf would diſcover what the ſtone was of which they were formed. And this was the more worthy of a diligent inquiry, ſince the petuntſe might eaſily be ſupplied by many of our own earths and ſands; nothing being required of that but a ſubſtance eaſily running into a white glaſs. But the difficulty of vitrifying this other ingredient renders it a thing much more difficult to be ſupplied by one of the ſame nature among ourſelves. The compariſon of theſe, with other mineral ſubſtances, ſoon proved that they were of the nature of talc; or, in other words, that kaolin was talc powdered, and made up into a paſte with water. And to be aſſured whether the whole maſs was talc powdered, or any thing elſe with a mixture of talc, he ſeparated the particles of the kaolin by water, and found the ſmall ones wholly the ſame with the larger; and that the larger, when reduced to powder alone, made with water a paſte wholly the ſame with the kaolin. It is well known, that the fragments of talc have a great reſemblance to the pearly part of ſome ſhell fiſhes: and hence unqueſtionably has ariſen the opinion of porcelain being made of ſea ſhells; ignorant perſons having ſeen the talc of kaolin, and taken it for a ſhelly matter. Talc has not yet been ſucceſsfully uſed in any of our European manufactures of porcelain; but it is eaſy to ſee, from many unanſwerable reaſons, that ſince China porcelain is made of a mixture of vitrifiable and unvitrifiable matter, nothing is ſo likely to ſucceed with us in the place of the laſt of theſe as talc.

1. We know no ſubſtance in the foſſile world ſo difficult to reduce to glaſs as talc, which, if put into the ſtrongeſt of our fires, in a crucible, is not to be vitrified, nor even calcined. 2. We know no ſubſtance which keeps ſo much brightneſs after having paſſed the fire as talc, or that is of ſo pure a white; whence we may alſo learn that it is not to the petuntſe alone, that the china-ware owes its whiteneſs, but that the kaolin is inſtrumental to the giving it that colour. 3. Talc is tranſparent, nay, and in ſome degree keeps its tranſparence after the action of the moſt violent fire. If we are to make porcelain of a vitrifiable and unvitrifiable matter mixed together, yet it is neceſſary that the unvitrifiable one ſhould retain its tranſparence, otherwiſe it would obſcure the maſs; and talc is therefore the only known ſubſtance qualified for this purpoſe. Perſons who have been at the china works, ſay, that the porcelain is made of equal quantities of petuntſe and kaolin, and it is therefore a juſt and exact ſemi-vitrification. 4. Talc is well known to have a great flexibility or toughneſs, and as it is found to preſerve this even after it has paſſed the fire; it is very probable, that it is owing to this property of the kaolin that the china-ware is ſo much leſs brittle than glaſs. Mem. Acad. Par. 1727.

It has been before obſerved, that we may eaſily, in Europe, be provided with different ſubſtances, which will, in our porcelain manufactures, ſupply the place of the petuntſe of China, and talc appears equally qualified to ſerve inſtead of the kaolin. For this purpoſe we may uſe the common Muſcovy talc, or iſinglaſs, uſed by our miniature-painters to cover their pictures inſtead of glaſs, and, by the curious, to preſerve objects for the microſcope; or perhaps the Venetian talc of the druggiſts would ſucceed even better: at leaſt the proceſs is ſo rational, as to be extremely well worth trying.

But this kaolin is more probably an argillaceous earth, from its forming with water a maſs tenacious enough to be made into the loaves into which it is brought over. M. Bomare ſays, that by analyſing ſome Chineſe kaolin, he found it was a compound earth, conſiſting of clay, to which it owed its tenacity; of calcareous earth, which gave it a mealy appearance; of ſparkling particles of mica, and of ſmall gravel or particles of quartz cryſtals. He ſays, that he has found a ſimilar earth upon a ſtratum of granite, and conjectured that it may be decompoſed granite.. This conjecture is the more probable, as kaolins are frequently found in the neighbourhood of granites. See CLAY, HOACHE, and PORCELAIN *Earth*.

Kiln

KILN, in *Agriculture*, a kind of oven or ftove for admitting heat, in order to dry fubftances of various kinds, as corn, malt, hops, &c. It alfo fignifies a fabric or building conftructed for the purpofe of burning lime-ftone, chalk, and other calcareous ftones, into lime. Kilns are of different kinds, and formed in different ways, according to the purpofes for which they are defigned.

KILN-*Afhes*, the afhes made in kilns where wood, ftraw, furze, &c. are burnt. Thefe afhes are ufeful as manure for almoft any kind of foil, but efpecially fuch as poffefs much vegetable matter. In the weftern diftricts, the farmers fift them over their corn and grafs; but this muft not be done in windy weather, becaufe they are fo very light, that they would eafily be blown away and loft. They are found to fucceed beft when laid on juft before rain falls. See ASHES.

KILN, *Brick*. See BRICK-*Kiln* and BRICK.

KILN, *Hop*, a ftove or kiln conftructed for the purpofe of drying or ftoving hops. See HOP and OAST.

KILN, *Lime*, a fort of kiln conftructed for the purpofe of burning various kinds of calcareous fubftances, fuch as lime-ftone, chalk, fhells, &c. into lime. They are built of different forms or fhapes, according to the manner in which they are to be wrought, and the kinds of fuel which are to be employed. It has been remarked, in a work on landed property, that, in places where materials are dear, from their being fetched from a diftance, and where the fuel is coals, and alfo expenfive, the form of a kiln is moftly that of an inverted cone, a form which has its inconveniencies; but in diftricts where the art of burning lime is practifed with fuperior attention and correctnefs, the form has of late years been gradually changing from conical to elliptical. But, in his opinion, "the beft form of a lime furnace, in the eftablifhed practice of the prefent day, is that of the egg placed upon its narrower end, having part of its broader end ftruck off, and its fides fomewhat compreffed, efpecially towards the lower extremity; the ground plot or bottom of the kiln being nearly an oval, with an *eye*, or draft-hole, toward each end of it." It is fuppofed that "two advantages are gained, by this form, over that of the cone. By the upper part of the kiln being contracted, the heat does not fly off fo freely as it does out of a fpreading cone. On the contrary, it thereby receives a degree of reverberation, which adds to its intenfity." But the other, and ftill more valuable effect is this: "when the cooled lime is drawn out at the bottom of the furnace, the ignited mafs, in the upper parts of it, fettles down, freely and evenly, into the central parts of the kiln; whereas, in a conical furnace, the regular contraction of its width, in the upper as well as the lower parts of it, prevents the burning materials from fettling uniformly, and levelling downward. They "hang" upon the fides of the kiln, and either form a dome at the bottom of the burning mafs, with a void fpace beneath it, thereby endangering the ftructure, if not the workmen employed; or, breaking down in the centre, form a funnel, down which the under-burnt ftones find their way to the draft-holes." And "the contraction of the lower part of the kiln has not the fame effect; for, after the fuel is exhaufted, the adhefion ceafes, the mafs loofens, and, as the lime cools, the lefs room it requires. It therefore runs down freely to the draft-holes, notwithftanding the quick contraction of the bottom of the kiln or furnace."

And, laftly, that, "with refpect to the lime-furnace (which is, he thinks, entitled to the moft fedulous attention of agricultural chemiftry), the fire requires to be furnifhed

with a regular supply of air. When a kiln is first lighted, the draft-holes afford the required supply. But after the fire becomes stationary, in the middle, or towards the upper part of the kiln (especially of a tall kiln), while the space below is occupied by burnt lime, the supply from ordinary draft-holes becomes insufficient. If the walls of the kiln have been carried up dry or without mortar, the air finds its way through them to the fire. In large deep kilns that are built with air-tight walls, it is common to form air-holes in their sides, especially in front, over the draft-holes. But these convey the air, in partial currents, to one side of the kiln only, whereas that which is admitted at the draft-holes passes regularly upward to the centre, as well as to every side of the burning mass; and, moreover, tends to cool the burnt lime in its passage downward, thereby contributing to the ease and health of the workmen. Hence he is of opinion, that the size of the draft-holes ought to be proportionate to that of the kiln, and the size of the stones taken jointly (air passing more freely among large than among small stones), and that the required supply of air should be wholly admitted at the draft-holes. By a sliding or a shifting valve, the supply might be regulated, and the degree of heat be encreased or diminished, at pleasure," according to circumstances.

The most ancient kind of lime-kiln is probably that which is made by excavating the earth in the form of a cone, of such a size as may be necessary; and afterwards building up the sides, or not, according to the circumstances of the case: the materials being then laid in, in alternate layers of fuel and stone, properly broken, until the whole is filled up. The top is then covered with sods, in order that the heat may be prevented from escaping; and the fire lighted at the bottom, and the whole of the contents burnt, in a greater or less space of time, in proportion to the nature of the stone, and the quantity that is contained in the kiln. From the circumstance of the top parts of these kilns, in some districts, being covered over, and the sides sometimes built up with sods, they are termed *sod-kilns*, in order to distinguish them from the other sorts. When the whole of the contents of such kilns are grown cold, they are drawn or taken out from the bottom; and the kiln again filled, if necessary. These kilns are obviously intended for burning only one kiln-full at a time. But as the burning of lime in this way is tedious and uneconomical, other methods and forms of kilns have been had recourse to. Where lime is much wanted, either for agriculture or other purposes, they therefore use perpetual kilns, or what are more generally known by the name of *draw-kilns*. These, as all lime-kilns ought to be, are, the author of Modern Agriculture says, situated by the side of a rising bank, or sheltered by an artificial mound of earth. They are generally built either of stone or brick; but the latter, as being better adapted to stand excessive degrees of heat, is considered as preferable. The outside form of such kilns is sometimes cylindrical, but more generally square. The inside should be formed in the shape of a hogshead, or an egg, opened a little at both ends, and set on the smallest; being small in circumference at the bottom, gradually wider towards the middle, and then contracting again towards the top. In kilns constructed in this way, it is observed, fewer coals are necessary, in consequence of the great degree of reverberation which is created, above that which takes place in kilns formed in the shape of a sugar-loaf reversed. Near the bottom, in large kilns, two or more apertures are made: these are small at the inside of the kiln, but are sloped wider, both at the sides and the top, as they extend towards the outside of the building. The uses of these apertures are for admitting the air necessary for supplying the fire, and also for permitting the labourers to approach with a drag and shovel, to draw out the calcined lime. From the bottom of the kiln within, in some cases, a small building, called a horse, is raised in the form of a wedge, and so constructed as to accelerate the operation of drawing out the burned lime-stone, by forcing it to fall into the apertures which have been mentioned above. In other kilns of this kind, in place of this building, there is an iron grate near the bottom, which comes close to the inside wall, except at the apertures where the lime is drawn out. When the kiln is to be filled, a parcel of furze or faggots is laid at the bottom; over this a layer of coals; then a layer of lime-stone, which is previously broken into pieces, about the size of a man's fist; and so on alternately, ending with a layer of coals, which is sometimes, though seldom, covered with sods or turf, in order to keep the heat as intense as possible. The fire is then lighted in the apertures; and when the lime-stone towards the bottom is completely calcined, the fuel being considerably exhausted, the lime stone at the top subsides. The labourers then put in an addition of lime-stone and coal at top, and draw out at bottom as much as they find thoroughly burned; and thus go on, till any quantity required be calcined. When lime-stone is burned with coals from $2\frac{1}{2}$ to $3\frac{1}{2}$ bushels, on a medium, 3 bushels of calcined lime-stone are produced for every bushel of coals used in the process.

A lime-kiln of this sort is described in count Rumford's Essays, which is in possession of the Dublin Society, as well as the principal objects that ought to be had in view in constructing of the kiln pointed out: the first of which is, "to cause the fuel to burn in such a manner as to consume the smoke, which has here been done by obliging the smoke to descend and pass through the fire, in order that as much heat as possible might be generated. Secondly, to cause the flame and hot vapour, which rise from the fire, to come in contact with the lime-stone by a very large surface, in order to economize the heat, and prevent its going off into the atmosphere; which was done by making the body of the kiln in the form of a hollow truncated cone, and very high in proportion to its diameter; and by filling it quite up to the top with lime-stone, the fire being made to enter near the bottom of the cone.

"Thirdly, to make the process of burning lime perpetual, in order to prevent the waste of heat which unavoidably attends the cooling of the kiln, in emptying and filling it, when, to perform that operation, it is necessary to put out the fire.

"And, fourthly, to contrive matters so, that the lime in which the process of burning is just finished, and which of course is still intensely hot, may, in cooling, be made to give off its heat in such a manner, as to assist in heating the fresh quantity of cold lime-stone with which the kiln is replenished, as often as a portion of lime is taken out of it.

"To effectuate these purposes, the fuel is not mixed with the lime-stone, but is burned in a close fire-place, which opens into one side of the kiln, some distance above the bottom of it. For large lime-kilns on these principles, there may be several fire-places all opening into the same cone, and situated on different sides of it; which fire-places may be constructed and regulated like the fire-places of the furnaces used for burning porcelain.

"At the bottom of the kiln there is a door, which is occasionally opened to take out the lime.

"When, in consequence of a portion of lime being drawn out of the kiln, its contents settle down or subside,

the empty ſpace in the upper part of the kiln, which is occaſioned by this ſubtraction of the burned lime, is immediately filled up with freſh lime-ſtone.

"As ſoon as a portion of lime is taken away, the door by which it is removed muſt be immediately ſhut, and the joinings well cloſed with moiſt clay, to prevent a draft of cold air through the kiln. A ſmall opening, however, muſt be left, for reaſons which are explained below.

"As the fire enters the kiln at ſome diſtance from the bottom of it, and as the flame riſes as ſoon as it comes into this cavity, the lower part of the kiln (that below the level of the bottom of the fire-place) is occupied by lime already burned; and as this lime is intenſely hot, when, on a portion of lime from below being removed, it deſcends into this part of the kiln, and as the air in the kiln, to which it communicates its heat, muſt ariſe upwards in conſequence of its being heated, and paſs off through the top of the kiln, this lime, in cooling, is by this contrivance made to aſſiſt in heating the freſh portion of cold lime-ſtone, with which the kiln is charged. To facilitate this communication of heat from the red-hot lime juſt burned to the lime-ſtone above in the upper part of the kiln, a gentle draft of air through the kiln, from the bottom to the top of it, muſt be eſtabliſhed, by leaving an opening in the door below, by which the cold air from without may be ſuffered to enter the kiln. This opening (which ſhould be furniſhed with ſome kind of a regiſter) muſt be very ſmall, otherwiſe it will occaſion too ſtrong a draft of cold air into the kiln, and do more harm than good; and it will probably be found beſt to cloſe it entirely, after the lime in the lower part of the kiln has parted with a certain proportion of its heat."

The height of the kiln, which is repreſented in *Plate* (*Kiln*) *Agriculture*, *fig.* 1. is on a ſcale of 15 feet: its internal diameter below, two feet; and above, nine inches. In order more effectually to confine the heat, its walls, which are of brick, and very thin, are double, and the cavity between them is filled with dry wood-aſhes. To give greater ſtrength to the fabric, theſe two walls are connected in different places by horizontal layers of brick, which unite them firmly: *a* is the opening by which the fuel is put into the fire-place: through this opening the air deſcends which feeds the fire. The fire-place is repreſented nearly full of coals, and the flame paſſing off laterally into the cavity of the kiln, by an opening made for that purpoſe at the bottom of the fire-place. The opening above, by which the fuel is introduced into the fire-place, is covered by a plate of iron, moveable on hinges; which plate, by being lifted up more or leſs by means of a chain, ſerves as a regiſter for regulating the fire. A ſection of this plate, and of the chain by which it is ſupported, are ſhewn in the figure: *b* is an opening in the front wall of the fire-place, which ſerves occaſionally for cleanſing out the fire-place, and the opening by which the flame paſſes from the fire-place into the kiln. This opening, which muſt never be quite cloſed, ſerves likewiſe for admitting a ſmall quantity of air to paſs horizontally into the fire-place. A ſmall proportion of air, admitted in this manner, has been found to be uſeful and even neceſſary in fire-places, in which, in order to conſume the ſmoke, the flame is made to deſcend. Several ſmall holes for this purpoſe, fitted with conical ſtoppers, may be made in different parts of the front wall of the fire-place.

The bottom of the fire-place is a grate conſtructed of bricks placed edgeways, and under this grate there is an aſh-pit; but as no air muſt be permitted to paſs up through this grate into the fire-place, the aſh-pit door, *c*, is kept conſtantly cloſed, being only opened occaſionally to remove the aſhes: *d* is the opening by which the lime is taken out of the kiln; which opening muſt be kept well cloſed, in order to prevent a draught of cold air through the kiln. As only as much lime muſt be removed at once as is contained in that part of the kiln which lies below the level of the bottom of the fire-place, to be able to aſcertain when the proper quantity is taken away, the lime, as it comes out of the kiln, may be directed into a pit ſunk into the ground in front of the opening by which the lime is removed; this pit being made of a proper ſize to ſerve as a meaſure for it. And while the lime is removing from the bottom of the kiln, freſh lime-ſtone ſhould be put into it above; and during this operation, the fire may be damped by cloſing the top of the fire-place with its iron-plate. Should it be found neceſſary, the fire, and the diſtribution of the heat may, in burning the lime, be further regulated by cloſing more or leſs the opening at the top of the lime-kiln with a flat piece of fire-ſtone, or a plate of caſt-iron. The double walls of the kiln, and the void ſpace between them, as alſo the horizontal layers of bricks by which they are united, are clearly and diſtinctly expreſſed in the figure in the plates.

This method of conſtructing lime-kilns, though ingenious and philoſophical, is probably much too expenſive for general uſe.

It is a common practice to burn lime-ſtone with furze in ſome places. The kilns which are made uſe of in theſe caſes are commonly known by the denomination of *flame-kilns*, and are built of brick; the walls from four to five feet thick, when they are not ſupported by a bank or mound of earth. The inſide is nearly ſquare, being twelve feet by thirteen, and eleven or twelve feet high. In the front wall there are three arches, each about one foot ten inches wide, by three feet nine inches in height. When the kiln is to be filled, three arches are formed of the largeſt pieces of lime-ſtone, the whole breadth of the kiln, and oppoſite to the arches in the front wall. When theſe arches are formed, the lime-ſtone is thrown promiſcuouſly into the kiln to the height of ſeven or eight feet, over which are frequently laid fifteen or twenty thouſand bricks, which are burned at the ſame time with the lime-ſtone. When the filling of the kiln is completed, the three arches in the front wall are filled up with bricks almoſt to the top, room being left in each ſufficient only for putting in the furze, which is done in ſmall quantities, the object being to keep up a conſtant and regular flame. In the ſpace of thirty-ſix or forty hours, the whole lime-ſtone, about one hundred and twenty, or one hundred and thirty quarters, together with the fifteen or twenty thouſand bricks, are thoroughly calcined. Kilns conſtructed in this way may be ſeen near Wellingborough, in Northamptonſhire, and other places in the northern parts of the kingdom. And in many of the northern counties of Scotland, which are ſituated at a great diſtance from coal, it is alſo a common practice to burn lime-ſtone with peat; and, conſidering the rude ill-conſtructed kilns which are uſed for he purpoſe, it is aſtoniſhing with what ſucceſs the operations are performed. In ſome of theſe diſtricts, it is ſtated that lime-ſtone is ſufficiently calcined with peats, laid *ſtratum ſuper ſtratum*, in kilns formed of turf; but, owing to the quantity of aſhes which fall from the peat, the quality of the lime is conſiderably injured; and from the open and expoſed ſituation of many of theſe kilns, the waſte of fuel is immenſe. But the moſt common method of burning lime-ſtone with peat, is in kilns conſtructed ſomewhat ſimilar to thoſe in the diſtricts where furze is uſed as the only fuel. There are in general only two arches, or fire-places, and the peats are thrown into the bottom of theſe archſe, the fronts of which are ſeldom cloſed up, by which means the wind has

often great influence in retarding the operation, and frequently prevents the complete calcination of the lime-ſtone. An improvement might, it is ſuppoſed, be made on theſe kilns at a very trifling expence: if an iron grate were laid acroſs the bottom of the arch, with a place below for the aſhes to fall down, and the front of the arch cloſed up by a door made of caſt-metal, one-third of the fuel might be ſaved, and the operation performed in a ſhorter time, and with a much greater certainty, than by the method now practiſed in ſuch kilns.

In the Communications to the Board of Agriculture, Mr. Rawſon aſſerts, that he has produced a conſiderable ſaving in the burning of lime, by conſtructing his kiln in the manner ſhewn at *fig.* 2. "It is made twenty feet in height; at the bottom a metal plate is placed one foot in height, intended to give air to the fire; over this plate the ſhovel that draws the lime runs. The ſloped ſides are ſix feet in height, the breadth at the top of the ſlope is eight feet, the ſides are carried up perpendicular fourteen feet, ſo as that every part of the inſide, for fourteen feet, to the mouth, is exactly of the ſame dimenſions. On the mouth of the kiln a cap is placed, built of long ſtones, and expeditiouſly contracted, about ſeven or eight feet high. In the building of the cap, on one ſide of the ſlope, the maſon is over the centre of the kiln, ſo that any thing dropping down will fall perpendicularly to the eye beneath. He is here to place an iron door of eighteen inches ſquare, and the remainder of the building of the cap is to be carried up, until the hole at the top be contracted to fourteen inches. The kiln is to be fed through the iron door, and when filled, the door cloſe ſhut. The outſide wall muſt be three feet at the bottom to batter up to two feet at top, and made at ſuch a diſtance from the inſide wall of the kiln, that two feet of yellow clay may be well packed in between the walls, as every kiln built without this precaution will certainly ſplit, and the ſtrength of the fire be thereby exhauſted. At eight feet high from the eye of the kiln, two flues ſhould be carried through the front wall, through the packed clay, and to the oppoſite ſides of the kiln, to give power to the fire." It is obſerved, that with this kiln, he has produced one-third more lime from a given quantity of fuel; and ſtones of bad quality will be here reduced into powder, and may be put into the kiln without the neceſſity of being broken ſo ſmall as is uſual. As many ſituations will not admit of building a kiln twenty feet high, while other ſituations may allow of its being built thirty or even forty feet (for it cannot be made too high), the diameter of the kiln ſhould be proportioned to the height to which it is carried up.

And it is further ſtated, as another application of this ſort of contrivance, that "for ſeveral years he has made uſe of a ſmall kiln in an outſide kitchen, the height nine feet, the diameter three feet and a half. In the ſide of the kiln next the fire, he had three ſquare boilers placed, one of them large, containing half a barrel, with a cock, which ſupplied the family with conſtant boiling water; for the two others, he had tin veſſels made to fit the inſide with cloſe covers, in which meat and vegetables with water were placed and put into the two ſmaller boilers, which never had any water, but had cloſe covers. The tin boilers were heated ſooner than on the ſtrongeſt fire, and when the meat, &c. were ſufficiently dreſſed, the whole was taken out of the metal boilers. At one ſide he had an oven placed for roaſting and boiling meat; the bottom was metal of twenty-ſix inches diameter, and one inch and a half thick, a flue from the fire went underneath. Even with the bottom of the oven, a grating nine inches ſquare was placed, which opened a communication between the oven and the hot fire of the kiln. The height of the oven was fourteen inches, ſhut cloſe by a metal door of eighteen inches ſquare, and the top, level with the mouth of the kiln, was covered by another metal plate of half an inch thick, on which was placed a ſecond oven; the heat which eſcaped through the half-inch plate, though not near the fire, was ſufficient to do all ſmall puddings, pies, breakfaſt-cakes, &c. &c. The meat in the large oven was placed on an iron frame which turned on a pivot and ſtood on a dripping-pan, and was turned by the cook each half hour. And over the kiln he had a tiled ſtage for drying corn, and a chimney at one ſide, with a cawl on the top, which carried off all ſteam and ſulphur: a large granary was attached to the building. It is added, that the lime, if ſold, would more than pay for fuel and attendance; and he has frequently had dinner dreſt for fifty men, without interfering with his family buſineſs in any great degree.

There is another form of lime-kiln, which anſwers extremely well for general uſe, repreſented at *fig.* 3. in the ſame plate. This is capable of being built without any very conſiderable expence.

It has been found, by experience, in ſome of the northern diſtricts, that lime-kilns are rendered much leſs liable to crack and burſt by having the outſide walls carried up in a ſquare manner, than on the uſual circular plan.

Kiln, *Malt*, a ſort of kiln contrived for the purpoſe of drying malt or any kind of grain upon. In the conſtruction of kilns of this ſort many improvements have lately been made. A deſcription of a kiln of this kind by Mr. Pepper, of Newcaſtle-under-Line, has been given, in which *fig.* 4. is the ground plan, ſuppoſed to be twenty feet ſquare, but, if required larger or ſmaller, by following the ſame proportion, it may be made to any ſize or ſituation. The dark ſhaded walls riſe four feet high, to put the reflector upon over the fire, and alſo what the ſide arches ſtand upon, the brick piers, that carry the ſpark-ſtone, and bearers that the tiles lie upon. Letter *a*, the fire-grate, which lies nine inches below the bottom edge of the reflector; *b*, bottom edge of the reflector; *c, c, c, c*, brick pillars nine inches ſquare, that carry the ſpark-ſtone; *d, d, d, d, d, d*, brick pillars nine inches ſquare, that carry the bearers for the floor tiles to lie upon; *e*, ſhews the bottom of the ſide arches on each ſide of the kiln; *f*, exhibits the ſpace between the fire-place and the ſide arches, for the man to go round to clean the kiln; *g*, the wall on each ſide of the kiln, that the ſide arches ſtand upon. *Fig.* 5. is a ſection of it; *g*, ſhews the ſection of the wall which the ſide arches ſtand upon; *h*, the door to go to the fire-place; *i*, the reflector of caſt iron that covers the fire; *k*, ſmall door in the reflector to feed the fire; *l, l*, the ears of the reflector that the iron pipes are fitted upon, which convey the ſmoke, &c. from the reflector round the kiln, to the chimney; *m*, what is commonly called the ſpark-ſtone; it prevents the kiln from being too hot in the middle, and aſſiſts in ſpreading the heat to the outſides; *n*, bearers of caſt-iron or wood, that carry the kiln floor; *o, o*, ſhew the ends of the ribs that carry the tiles; *p*, the kiln tiles, that the malt lies upon; *q*, the ſteam-pipe that conveys the ſteam from the malt; *c, c*, brick pillars nine inches ſquare, that carry the ſpark-ſtone; *d, d*, brick pillars nine inches ſquare, that carry the bearers for the floor tiles to lie upon; *e, e*, ſhew the arches on each ſide the kiln; *u u*, denotes the ſituation of the pipes under the floor. And *fig.* 6. is a plan of the kiln floor, and ſhews the ribs that the kiln-tiles lie upon; *o, o*, the caſt iron or wood ribs that the tiles lie upon; *n, n*, the bearers that carry the ribs; *d, d*, the tops of the brick

pillars that carry the bearers, &c.; *b*, the reflector that covers the fire, which is of cast iron, about an inch thick, hollow, and on a semicircular plan, as shewn in the figures; *r, r*, the iron pipes that convey the smoke and heat from the reflector, round the kiln, to the chimney, which lies about three feet under the kiln floor, and about the same distance from the side walls, which are supported by iron stays from the side arches; *s, s*, the ends of the iron pipes that go into the chimney; *t, t*, registers to regulate the draught and heat of the kiln; and *fig.* 7. is a section of the chimney.

It is noticed that in the plate the pillars, bearers, &c. that belong to the same thing, are marked with the same letters in all the different figures.

Another kiln of the same sort, invented by Mr. Joseph Coppinger, of Harbour View, near Cove, Ireland, is represented at *fig.* 8. This is stated to be particularly adapted to the use of farmers, who, in wet seasons, often lose quantities of grain for want of such convenience. The advantages it appears to possess above the kilns now in common use, are many; first, it may be erected for one-tenth of the expence, if the value of the separate buildings be taken in, which are now almost invariably allotted for this purpose; secondly, any kind of fuel may be used without prejudice to the malt or corn to be dried in it: thirdly, the heat (by the construction of the flues) will be more regularly and evenly distributed without any waste, as at present: fourthly, the health of the people attending, will not, as at present, be exposed to certain injury, by always breathing and sleeping in a heated and unwholesome atmosphere, as their beds will be placed in a shed on the outside of the building. This, in his mind, is the most important part of the plan, and highly worthy the attention of every humane and considerate employer in this way: fifthly, this construction of a kiln may be erected on a loft or ground floor. If in the latter situation, sufficient elevation should be given to the fire-place, so as not to impede the draught. These are the principal advantages that occur to the writer. If the experience of others confirm them, he will be highly gratified: *a*, the main walls; *b*, the flues; *c*, the chimnies; in each of which may be placed a metal damper to regulate the heat. It is recommended, in the case of a new building, to carry up the flues of the chimnies in the thickness of the walls. In a house already built, they may be carried up either inside or outside the building: *d*, the fire-place, which may be divided, or in one, just as desired, by which the half or the whole may be heated, as is most convenient.

It is stated that kiln tiles eighteen inches square, and two inches thick in the solid, with a lapping of half an inch broad and one inch deep round the edge of each tile, are proposed for covering the flues, which, if fairly cast, may be laid dry, without mortar. If it should be difficult, or too expensive, to procure tiles of eighteen inches, nine inches can be made to answer. The flues are proposed to be divided by a brick, on edge, so as that every eighteen-inch tile will cover two flues. The breadth of the flues may be six inches and a half, and ten inches high. This proportion, it is hoped, will be found to answer in most cases; but it may be varied according to the better judgment of the party erecting. The sides and bottoms of the flues should be plastered. The platform of this kiln should, in all cases, be well rammed with earth, and made perfectly level before laying out the flues. Iron grate-doors are intended to be hung on hinges, in a recess, at the mouth of each flue, to prevent them being choked with large pieces of cinder, or other substances. It is also intended that these doors should shut and open at pleasure, as may be found necessary in carrying on the business.

KILN *Tiles*, in *Rural Economy*, the name of that sort of tiles which are employed in malt and other similar sorts of kilns.

KILN *for tin-ore*. The place where the tin-ore is roasted in order to burn away the mundic, and other sulphureous matters that are mixed with it, is called the *tin-kiln*. This is of a very plain structure; its hearth or floor is made of one large stone, and this is covered with another, supported at six inches height above it. The uppermost has a hole in the middle, through which the ore is poured on the under one; and when it is distributed over it in a bed of three or four inches thick, it is burnt by means of a fire of furze bushes kept underneath, and communicating with the space between the two stones by an aperture behind; the lower stone not reaching the wall by six inches.

When the sulphur is all burnt away by the fire, and the flame is no longer blue, the whole bed of roasted ore is thrust off the stone by the rake into the aperture behind, through which it falls into the open fire. The fire is kept up with new bushes, and there is a new bed of ore thrown in at the hole above. Thus the fire is kept up day and night, and supplies of fresh ore made through the hole by the black tin brought from the buddles of washing troughs. When the lower part of the furnace is filled up with the ore thrown into it, there is a hole behind the kiln, through which this ore, and the coals and ashes, are all raked out together, and left in the open air to cool; and the whole mass thus raked out, will sometimes be several days in cooling, the mixture of coals among it keeping it red-hot for a considerable time. When it is taken away from behind the furnace, it is washed again before it is put into the melting furnace. It is observed, that the different ores require for this last operation a different proportion, and different sort of fuel. The moor-tin, that is, such ore as is dug up in the moory countries, melts best with moor-charcoal charred; but that dug on the hills is found to run best with a mixture of charcoal and peat in equal quantities. The stones used for the kilns are always moor-stone. Phil. Transf. Nº 69.

KILN, in *Ship Building*, a convenience for boiling or steaming planks to make them pliable. A boiler-kiln is either made of sheet-copper, bottom and sides rivetted together, or the bottom of sheet-copper and the sides of lead, rivetted and soldered together. This is fixed in a body of brick-work, and under each end, or in the middle, are furnaces to cause the water to boil after the planks are in. The upper part, to preserve the steam and facilitate the boiling, is inclosed by shutters, opening by hinges and small tackles.

Dimensions of a Copper Boiler

	feet.	*in.*
Long - - - - -	40	0
Broad at the ends - -	4	3
———— middle -	6	0
Deep - - - - - -	2	10

And weighed 53cwt. 3ft. 14lb.

A steam-kiln is a trunk composed of deals grooved and tongued together edgeways, and is from three to four feet square, and from 40 to 60 feet long, and has a door at each end. It is confined together by bolts driven through the sides at certain distances, which answer the purpose of bearers, whereon the planks rest while steaming. It is supported, about four feet above the ground, upon a strong framing of wood. Underneath it, in the middle, is fixed, in brick-work, a large copper or iron boiler, or, which is better, one towards each end; the steam from the boilers, issuing into the trunk wherein it is confined, enters into the pores of the plank, and renders it very pliable.

Laboratory

LABORATORY is a place furnifhed with chemical apparatus, and entirely devoted to the different operations of chemiftry, whether on the fcale of chemical manufacture, or for the purpofe of experimental refearch. In the prefent article, however, we fhall confine ourfelves to the latter, fince it is more proper to defcribe the apparatus ufed in the large way under the manufacture of the refpective articles. Although many of the moft diftinguifhed labourers in chemical fcience have been content with fuch apparatus as they have made themfelves, or converted from the common domeftic utenfils; it muft, neverthelefs, be obvious, that they would have fucceeded better with well contrived and appropriate apparatus, and their refearches would, in all probability, have been much more extended.

Every chemical experimenter will find a confiderable advantage in fo much mechanical talent, as will enable him to make, or repair at leaft, the moft common of his apparatus. For this purpofe he fhould poffefs a fet of mechanical tools, fuch as a lathe and vice, with files and rafps for metal and wood. The tools for making fcrews, as well in the lathe as by the *fcrew-plate* and *taps*, will alfo be neceffary. To thefe fhould be added a fmall forge, anvil, and hammer, for the purpofe of forging fmall articles. A fet of brazier's and tinman's tools will be found very ufeful, and a little experience will enable the operator to make any article of tin or copper, which is not very complicated. In addition to the above, the glafs-blower's lamp and bellows will be of effential fervice for fealing and bending glafs tubes, and other purpofes.

Some of thefe may appear unneceffary, efpecially in large towns, where the different artifts may be found, but it will be ftrongly in the recollection of all who have had occafion to get apparatus made, that they can feldom get them conftructed to their wifh, although they ftand by the artift. The want of proper tools, and a little mechanical dexterity, have frequently prevented or put an end to experimental inveftigations of confiderable importance. Independent of the apartment containing the mechanical apparatus, the chemift will require at leaft one diftinct room for a laboratory. Two rooms, however, fhould be employed when it is convenient. The principal room of the laboratory fhould be on a ground floor, for feveral reafons. A furnace for great heat fhould be in a low room, in order to have the greateft length of chimney. The afh-pit of this furnace fhould terminate in a cellar under the laboratory, in order that the air may enter perpendicularly, and of the loweft poffible temperature. See FURNACE.

That fide of the laboratory allotted for furnaces fhould have an arch projecting into the room about three or four feet, and of fuch height that a perfon may freely walk under it. In the higheft part of this arched portion muft be an opening into a chimney diftinct from the reft, and built up in the fame ftack.

It will be found more convenient to ufe portable furnaces for moft purpofes, having none fixed but for producing very great heats, upon a larger fcale, and what are generally denominated melting furnaces.

The iron chimney of the portable air-furnace may be carried to any height, and placed under or within the chimney, ufed for the efcape of fmoke and vapours.

A chimney with a funnel may, in the fame way, be placed over the mouth of the portable blaft furnace, invented by Mr. Aikin. This furnace may be fo contrived that when the body of it is removed, the bafe may form a forge hearth, which will be found very ufeful. For the varieties of furnaces ufed in the laboratory, fee FURNACE.

On another fide of the laboratory muft be placed a ftone trough or fink, joined to a tub or ciftern of water, which can be filled and emptied at pleafure, by means of a ftop-cock, over it, and a plug in the bottom. Over the fink-ftone fhould be fufpended a rack for holding bottles and glaffes to drain after wafhing. On the fame fide may be placed a large block of wood or ftone, for the purpofe of holding a mortar or anvil occafionally.

A third fide of this room muft be occupied by cupboards and fhelves, for holding the different apparatus of glafs and earthen ware, and for the different fubftances hereafter to be mentioned.

The fourth fide, which fhould be the lighteft, muft be provided with a table the whole length of this fide, in the front of which, down to the floor, fhould be a number of drawers for holding all the dry fubftances. This table is for making the experiments upon, and for holding the apparatus in ufe at any time.

If poffible, every laboratory fhould be joined to a fecond room, however fmall it may be, in which to perform the very nice and delicate experiments, and for keeping a few books, and choice inftruments of metal, fuch as balances, &c. This room fhould be kept very clean and dry, and as free as poffible from fteam and the fumes of acids.

If any part of the furniture require to be painted, the paint fhould be made with fulphat of lead, fince it is not acted upon by acids. This fubftance has been ufed by Dr. Henry not only for this purpofe but for repairing broken glafs and labelling bottles. The following are the moft particular apparatus with which a laboratory fhould be furnifhed.

Mortars.—Thefe are of various kinds, caft-iron, bronze, fteel, and Wedgewood ware. The caft-iron mortar is generally ufed for vegetable fubftances, and fuch as are not liable to grind off the iron. The hardnefs of this inftrument is

much increafed by cafting the interior furface upon a metal mould, of the greater weight the better.

The hardnefs of the bronze mortar, which is generally ufed for the fame purpofes, may be increafed by the fame means.

The fteel mortar is ufed for reducing very hard minerals into fmall bits, fitted for grinding in the mortar of agate. It confifts of a cylinder of hardened fteel, with a flat bottom, and a peftle of the fame made to fit the mortar, accurately, from top to bottom. It is ufed by putting the pieces of the mineral into it, and ftriking the peftle with a hammer. By this means it can be reduced into tolerably fmall particles, without grinding off any portion of the mortar.

Hardened fteel mortars of the common fhape would be of great ufe, but it would be difficult to harden fo large a mafs without cracking. It might perhaps be made by welding a plate of caft fteel upon a thick piece of iron, and afterwards working it into the required fhape, and polifhing it in the infide. If the fubftance is not very particular, it may be ground in a mortar of Wedgewood ware If, on the contrary, it be very hard, the matter from the mortar will be liable to be mixed with the powder. In this cafe the agate mortar is much to be preferred; fome ftones are, however, fo hard as to act upon the agate. In this inftance, the matter to be ground fhould be weighed before and after grinding, and the increafe of weight may be fafely deemed filex, and allowed for in the analyfis accordingly.

Balance.—This inftrument is of great importance to the analytical chemift, and ought to weigh 100 grains to the $\frac{1}{1000}$th of a grain. A very mafterly account of the principles and conftruction of the balance will be found under the article BALANCE.

It will be almoft unneceffary to obferve, that fo delicate an inftrument fhould be kept in a feparate apartment from the laboratory where fumes of acids do not prevail. It fhould be clofely fhut up in a glafs cafe having a fliding door in the front. The ftrings to which the fcales are fufpended, fhould be of fine gold or filver cord, and the fcales of filver or platina, and very thin. One of the fcales fhould be provided with a loofe pan of very thin platina, and balanced with the other, for the purpofe of holding the fubftance to be weighed. The weights for chemical fubftances fhould be reckoned in, and marked with grains and decimals of grains.

Lamp.—This valuable inftrument is a very great improvement upon the fand-bath. Its heat is regular, and may, by means of the concentric wick, be made of fufficient intenfity for moft purpofes. Its greateft advantage, however, confifts in the facility with which it can be applied or withdrawn without lofs of time. See LAMP.

For nice and delicate purpofes, where the heat of the lamp is required, alcohol, inftead of oil, gives an intenfe and fteady heat, and is not very expenfive when a proper veffel is ufed for burning it. The latter kind of lamp is particularly adapted for a public lecture.

Fig. 1. *Plate* XVI *Chemiftry*, is a ftand fupporting the lamp, and at the fame time the fubftance to be heated, and the connecting apparatus A B is a frame of wood. F a pillar of wood or iron, fmooth and cylindrical throughout, fo as to admit of the fliding rings, fuch as *g*, to move freely without fhaking. C is the Argand lamp, having a chimney at *o* of iron. This chimney confifts of two concentric tubes, connected together by fmall wedges of baked clay, or fome other incombuftible fubftance which is a bad conductor of heat. This contrivance not only economizes the heat, but keeps the outer tube fo cool, that it may be taken hold of with the fingers. In this lamp the wick is raifed by the fcrew, inftead of the rack, which is performed by turning the chimney round.

The funnel-fhaped ring D is an improvement upon the common ring ufed for fupporting the retort. It confifts of a number of conical hoops, one fitting upon the other, fo as to hold different fized retorts. The fmalleft hoop is about two inches in diameter, and the largeft, which is attached to the fliding part, about five inches. The conical furface directs the heat to the retort, which on the common plan only ferves to annoy the fingers and face of the operator, and at the fame time heats the neck of the retort, where the condenfation of the vapour fhould take place: *f* is a retort fupported by the ring: *g* is a flider, having two prongs at *p* to keep the retort from falling fideways: E is a receiver to receive the contents of the retort, which may be either ufed alone, or with Woulfe's bottles *a*, *b*, *c*, hereafter to be defcribed. G is a ftand, with three inclined prongs of wood to fupport receivers of different fizes, and which may be placed at different elevations by means of the fcrew *n*.

Retort.—*Fig.* 2. This is a chemical utenfil of very ancient origin, and is the moft fimple apparatus for diftillation Retorts are of glafs, earthen-ware, and metal. Thofe of glafs are fometimes of green glafs, particularly when fuch heat is employed in the naked fire, as might foften the more fufible white glafs. Thofe of flint-glafs fhould be as thin as poffible, in order to avoid breaking by an unequal expanfion. When the retort is provided with a glafs ftopper, as at *a*, it is faid to be tubulated.

This appendage is neceffary only, when fome fluid, fuch as an acid, has frequently to be added, or when it would be difficult to get the materials into the mouth of the retort. In order to add any fluid from time to time while the procefs is going on, the veffel (*fig.* 3) called an *acid holder* is made to fit in the place of the ftopper of the retort, the part *d* being ground to fit the fame. The acid is put into this veffel, and let into the retort, by a little at once, through the glafs ftop-cock *c*.

When the retort is ufed for purpofes of diftillation, the neck is fitted or luted into the neck of the receiver (*fig.* 4) This receiver is ufed for the diftillation of liquids, the vapours of which are eafily condenfible, fuch as water or alcohol. When the vapours, coming over, are accompanied with elaftic fluids, which are incondenfible, the receiver (*fig.* 5.) is better adapted. If the elaftic fluid be of no importance, and inoffenfive, it may efcape at the conical ftopper of the latter veffel every time the preffure is fufficient to raife it. It is, however, fometimes neceffary to collect the gafeous fluid. In this cafe the bended tube (*fig.* 6.) is put into the place of the ftopper (*fig.* 5.), the other end terminating in a pneumatic apparatus where the gas is collected. In the diftillation of very volatile liquids, fuch as ether, it is fometimes neceffary to remove the receiver to a diftance from the retort, by placing between them an intermediate veffel, (*fig.* 7.) called an *adopter*. The receiver (*fig.* 8.) is employed for collecting the product of different degrees of ftrength by the application of the bottle *b*.

In the diftillation of fubftances, which require a greater heat than glafs will bear, earthen retorts are employed. They are of the fame fhape with thofe already defcribed, and fhould be made of the materials with which crucibles are made. This fort of retort is generally ufed for the diftillation of phofphorus. If its texture be not clofe, the phofphorus will efcape in vapours through the pores. This, however, may be prevented by covering the furface with fome glazing material. Iron retorts, from their great firmnefs, are well adapted for diftilling fuch fubftances as will have no

chemical action upon them. Hence they are unfit for distilling sulphur, phosphorus, and acids, but are extremely proper for ammonia, mercury, and pitcoal. A retort of lead is used for the distillation of fluoric acid, owing to that acid combining with the silex of glass.

Woulfe's Apparatus.—In the distillation of substances which are merely to be raised into vapour by heat and condensed by cold, the retort, or still, with the receiver and the proper means of producing cold, are the only apparatus necessary. There is another distinct branch of distillation, in which the product is a gas, which is incondensible at the common temperature, and requires to be absorbed by water, or by some other substance dissolved in that liquid. In these processes, therefore, the temperature and size of the receiving vessels are not of so much importance as the exposure of the gaseous product to the greatest possible quantity of the absorbing liquid. Before the discovery of this most useful apparatus by Mr. Woulfe, from whom it takes its name, the common retort and receiver were used for all purposes. The elastic fluids were in consequence either compressed, and the operator was constantly in danger of being injured by the bursting of vessels, or, to remedy that evil, they were suffered to escape, and he was perpetually annoyed by the suffocating fumes which were set at liberty.

In *fig.* 1. the retort contains the materials for furnishing the elastic fluid to be absorbed by some liquid contained in the receiver E, and the succeeding bottles *a*, *b*, *c*, with their connecting tubes *r*, *b*, *t*: *v* constitutes the *Woulfe's apparatus*. A certain portion of the gas is taken up by the liquid in the receiver E. The excess passes through the tube *r* to the bottom of the liquid into the second receiver, by which another portion of the gas is absorbed. The residual gas passes along the tube *t* to the third receiver, which gives the gas a third chance of absorption. In this way it may be made to pass through any number of bottles, according to the greater or lesser facility with which the gas is absorbed. The last tube *v*, which is provided with a column of mercury, conveys the remaining gas, which is presumed to be unabsorbable, into the atmosphere, or it may be collected by a jar in the pneumatic apparatus. When the gas ceases to be furnished from the retort, in a quantity equal to the absorption in the receiving vessels, a retrograde motion will begin to take place. Atmospheric air will enter at the tube *v*. The liquid in the last receiver will be forced by its pressure into the preceding one, and if the absorption were to become complete, the whole of the liquid would be carried into the first receiver, and from thence to the retort. This evil has been very completely removed by what is called a tube of safety *f*, *l*, *x*.

Fig. 1.—The bulb *l* contains as much mercury as will be contained from *q* to *x*, so that when the gas, from defective absorption, accumulates in E, till its force is equal to the pressure of such a column, the excess of gas will bubble through the mercury into the atmosphere. On the contrary, when the absorption of the gas exceeds its evolution, the pressure of the atmosphere, to restore the equilibrium, will cause the mercury to occupy the ball *l*, and common air will bubble through it into the vessel E. Although this ingenious contrivance completely prevents any evil arising from the inequality of internal pressure, it is very objectionable, owing to its delicate structure, on which account it is constantly liable to be broken.

We are indebted to Mr. Knight for a great improvement on the tube of safety. This consists in having a valve of glass, similar to that of the *Nooth's apparatus* (described below), placed between the first and second vessel, so that the liquid in the succeeding bottle can never have a retrograde motion. To this valve there is no other objection than the difficulty of getting it made in places distant from the metropolis, and its liability to be fast, especially in making crystalline salts, such as the oxymuriat or carbonat of potash.

The same objection which we have made to the tube of safety, we are sorry to say applies to the whole of the *Woulfe's apparatus*. The connecting tubes are with very great difficulty ground into bottles, which makes the apparatus very expensive, and then are so liable to be broken, as to render it frequently useless.

We have before hinted, that the essential part of such an apparatus, is to expose the greatest possible quantity of the gas and the liquid to each other in a given time. In the Woulfe's bottles, this advantage does not obtain in so great a degree as might be effected in a simpler apparatus. We shall here subjoin a description of an apparatus of this kind, answering all the purposes to which the Nooth's and Woulfe's apparatus are separately applied. Although it has not been before made known, it has been used with great success by the writer of this article, and will no doubt be found an acquisition to the experimental as well as the manufacturing chemist.

Fig. 9. *Plate* XVII. *Chemistry*, is a representation of the apparatus for the absorption of gases. A is a retort from whence the gas is furnished, connected with the first bottle B, which contains the liquid to be impregnated, and into which the tube *a* is ground, reaching near to the bottom, so that when the gas enters this vessel, the liquid will be raised into the bottle C; at the same time the tube will be constantly filled, with the exception of the space occupied by bubbles of gas passing through it. If the gas is not all absorbed during its passage through this tube, the excess will pass down the tube *b* into the bottle D, which also contains the absorbent liquid. The same takes place in this bottle which is observed in that of B. The liquid ascends into the bottle E, the gas following it as before. The residual gas, should there be any, may either be conveyed into another bottle situated like D, or may be collected in a pneumatic trough, or escape through the tube of safety *e*.

This apparatus was invented for the purpose of making the oxymuriats of the earths, for which it is admirably adapted. The earths which are mixed with the water being constantly at the bottom, if not kept in agitation, the absorption is very slow and imperfect. In this apparatus no agitation is necessary. The earth, which is at the bottom of the vessels B and D, is first raised into the tubes *a* and *c*, and becomes as much exposed to the gas as any part of the liquid medium. The tubes *a* and *c* are each about two feet long, but they do not require to be so long for most experiments of this kind. Their diameter is about $\frac{1}{2}$ inch, so that in the course of about one minute, no less than about nine ounces are brought in contact with the gas, independent of the circular surfaces in the bottles.

In the common sized Woulfe's bottles, the tubes through which the gas enters seldom dip more than three inches into the fluid, so that we may safely rate the apparatus proposed as equal to at least eight of Woulfe's bottles. These bottles are the same with those of Woulfe's; the tubes are much simpler, and being stronger are less liable to break. Another great advantage is that of its not requiring a *tube of safety*. The great facility with which it can be applied to all the purposes of the Nooth's apparatus, as well as the Woulfe's, and with much more effect, will be soon appreciated. Under the article WOULFE will be found the description of a differently constructed apparatus. See *Plate* V. *Chemistry*.

Nooth's Apparatus.—This is represented in *fig.* 10. *Plate* XVI. It consists of three vessels fitted together by

ground joinings. It differs in its use from the Woulfe's, in being solely adapted for impregnating water and other bodies, with such gases as are disengaged from their combinations without heat, such as the carbonic acid, and sulphuretted hydrogen. The lower vessel A contains the substance from which the gas is obtained, such as carbonat of lime; the sulphuric acid being introduced occasionally at *d*; the gas enters the vessel B through the glass valve *a b*. This is magnified in *fig.* 12. The tubes *b* and *d* are at first in one piece and ground into the part *a e*; the portion *c* is then cut away, to make room for the hemispherical valve, the under side of which is ground flat, to fit the end of the tube *b*. The valve, on being raised by the gas, instantly falls and prevents the water from descending into the lower vessel. The air then enters the liquid in B, *fig.* 10. through small holes to disperse it as much as possible. When the gas accumulates in B, a portion of the liquid is driven up into the vessel C, the bubbles of air following it tending still more to promote the absorption. The air in C, if not absorbed, will at certain intervals raise the conical stopper *e*. This stopper should be so heavy as just to rise before the vessels would burst, and should be so conical as not to stick in the least degree. After the liquid is impregnated it is drawn off at the cock D.

Fig. 11. is a simpler and better apparatus for this purpose, invented by Dr. Hamilton. It is simpler, because the vessels are fewer, and the valve, which is complicated and liable to be fast, is dispensed with; and it is better because the gas comes in contact with more of the liquid in a given time, and consequently the absorption is effected sooner. The gas is furnished by the retort B, ground into the vessel A. From the latter the absorbing liquid is raised into the vessel C, till the air bubbles go through it, and if not absorbed passes out at *d*. This apparatus wants nothing more than a tube of greater length, for the gas to pass through, to make it complete.

In comparing the two last with that of *fig.* 9, the latter will be found much superior even to that of *fig.* 11.

Gasometer and Gas Holder.—The difference between these two vessels, consists merely in one having the means of measuring the quantity of gas which it contains at any time, and the other not, while both are employed as gas holders.

The gasometer was made a very expensive and magnificent apparatus by the celebrated Lavoisier, at the time he prosecuted his experiments upon elastic fluids. This instrument, much simplified, we shall describe in *fig.* 13. *Plate* XVII. A is a vessel containing water or some other liquid, which will not be acted upon by the gas to be held in it. B is a vessel inverted in the vessel A, and capable of moving up and down in it. E and F are cords by which the vessel B is suspended, the weights and pullies being concealed in the tube C D. *Fig.* 14 is a section to shew the interior parts of this apparatus K L is an interior vessel of the same shape, with the vessel B soldered to the bottom of the vessel A, so that no water or other liquid in A can communicate with the inside of it. This is done for the sake of using less of the liquid employed, which in the mercurial gasometer is very desirable, as well for the sake of economy, as making the apparatus more portable; *a* is a pipe passing through the middle of the vessel K L, and communicates with the tubes *o* and *d*. The air is introduced at the stop-cock *e*, and passing along the pipes *o* and *a*, raises the vessel B, which is counterpoised by the weights *r* and *q*. These weights are conducted down the middle of the tube C D, by the small pullies *x x* and *y y*. The tube *d*, which, with that of *o*, is common to the tube *a*, is to let the air out of the gasometer at the stop cock *f*, so that the air passes through *a*, both in its entry and its exit: *g*, *fig.* 13, is a flexible tube, serving to conduct the air to a pneumatic trough for examination, or for using the blowpipe when the vessel contains oxygen. This apparatus is provided with a graduated scale G, which tells the number of cubic inches contained in it. It is this scale which constitutes it a gasometer, without which it would be simply a *gas-holder*.

The mercurial gasometer is on the same plan with the above, but the materials must be unsusceptible of the action of the mercury. The vessels are generally made of cast-iron. The outer and the fixed inner vessels may be cast in one piece. The moveable vessel may be of the same metal, or of glass. The pipes must be of wrought iron, and accurately ground into the cast iron. Two gasometers with water, and one with mercury, will be indispensable in experiments in gaseous chemistry.

A very ingenious apparatus, answering the common purposes of gas-holder and gasometer, and in many instances the pneumatic trough, has been invented by Mr. Pepys. It consists of a tin vessel A, *fig.* 15, and a pan or tray B connected with it by pillars. The pipe *a* opens into the middle of the tray, and proceeds in a contrary direction near to the bottom of the vessel A: *v* is another pipe which also communicates with the tray, and just enters the vessel A: *r s* is a glass tube cemented firmly into two brass sockets, which communicate with the top and bottom of the vessel A. This tube is graduated, and shews how high the water stands in the vessel, and consequently tells the quantity of air contained in it. The vessel A is first filled with water by opening the cocks *a* and *v*, and shutting that of *n*, C being closed at the same time. The tray is now filled with water, which descends through the tube *a* into A, while the air in the same escapes at the opening into the tray, from *v*. When the vessel A is full of water, the cocks *a* and *v* must be closed, and the plug may be taken out of C. If the vessel and pipes be air-tight above, no water will be discharged at C, since this pipe is inserted at such an angle into A, that the lowest part of the outer end is higher than the highest part of the inner end. The next thing is to fill the vessel with gas, and for this purpose the neck of a retort, or other tube from which the gas is to proceed, should be introduced at *c* till it passes the inner end of the same The gas will rise in bubbles into the upper part of the vessel, while the same quantity of water will run out at the pipe C into an open vessel placed under it. When the water ceases to run out, and air-bubbles escape at C, the tube from whence the gas was furnished may be withdrawn, and the screw-plug put in its place.

In order to transfer the gas from this vessel into a jar, the tray must be filled with water, and also the jar, which must then be placed over the aperture from *v*. On opening the stop-cock *v*, that of *a* being previously opened, the air will ascend into the jar, while the same quantity of water will descend into the vessel A, to supply its place.

This apparatus may be used for several other purposes. A bladder may be tied to the stop-cock *n*, which being opened at the same time *a* is opened, the bladder will be filled with the gas. A flexible tube may be screwed on the same stop-cock for making experiments with the blow-pipe. The gasometer, *fig* 13, will be found better for the blowpipe, on account of the equable pressure in the apparatus last described.

Pneumatic Trough—This is a simple trough or cistern made of tin or copper japanned, and is used for collecting different gases. The size is generally about 18 inches long, 12 wide, and 12 deep. *Fig.* 16. *Plate* XVI. represents this trough. A is a sliding shelf which can be taken out. It is formed of two plates laid together; the under plate is made so concave, that when the convex side touches the upper plate in the middle, they are distant at the edges about one inch.

A rim being foldered round the two gives the fhelf the appearance of a folid, concave on the under fide and flat on the upper fide.

Any gas coming from the retort B, paffing under the fhelf in any fituation, muft be determined to the round hole in the middle, which is about half an inch wide. The trough, when ufed, is filled with water about an inch above the fhelf, the jar C being filled with the fame, and placed over the aperture through which the bubbles afcend. The ftand D, having a foot of lead or iron, will be found very ufeful for fupporting a retort or other veffel in thefe experiments. When a number of veffels are occupying the fhelf, and frequently fome are very tall, and of fmall diameter, it will be found neceffary to fupport them to prevent their being thrown over. This may be effected by having a number of fupporters of different fizes, fuch as A. This is better reprefented in *fig.* 17. At *d* is a focket to fit the pins which furround the fhelf; *n, o*, are fpringing claws to embrace the glafs.

In making experiments upon gafes, a number of veffels, fuch as *fig.* 18, will be neceffary. Thefe are generally called eudiometer tubes, fome of them are graduated into cubic inches, for the purpofe of meafuring the volume of gas ufed, or refulting from any experiment. See EUDIOMETRY.

Befides the trough already defcribed, which is ufed with water, it is neceffary to be provided with one for mercury. Indeed the latter is abfolutely indifpenfible when the gafes, which are the fubject of experiment, are abforbable by water: fuch as the muriatic acid gas, and ammoniacal gas.

Fig. 19. is a view of the mercurial trough: it is generally made of a folid block of fome hard wood, or of marble; or it may be made much neater, and with lefs labour, of pieces of wood joined together, clofely and firmly by iron fcrews. The firft cavity, *a e b*, may be about eight inches long, four inches broad, and one inch in depth: the fecond or lower cavity, *d*, fhould be about $6\frac{1}{2}$ inches long, $1\frac{1}{4}$ wide, and the fame depth: *c* is a fmaller cavity, about $\frac{3}{4}$ of an inch wide, $1\frac{1}{2}$ long, and one inch deep. The cavity *d* is intended to receive the glafs jar, *fig.* 20, for the purpofe of filling it with mercury: *a, b*, are fmall cavities in which to introduce the fingers for the purpofe of raifing the jar when full of mercury. The cavity at *c* is to place the inverted jar over, for the purpofe of introducing any gas into it. The fide *a c* anfwers as a fhelf to reft the inverted jars upon: *fig.* 21. is a ring of iron, with a leg to flip into holes on the fide of the trough, for the purpofe of fupporting the jars, which would otherwife be liable to fall on account of their fmall bafe.

Eudiometer.—Formerly the ufe of this inftrument was confined to the analyfis of the atmofphere. It has now, however, become of great importance in gafeous chemiftry, and has been confiderably improved within thefe few years.

In order to afcertain the nature of, and to diftinguifh the different gafes, chemifts have generally recourfe to fome fubftance capable of abforbing the gas under examination. The eudiometer is the veffel which contains, or communicates with the fubftance which is to abforb the gas, and the tube being graduated marks out the quantity abforbed, and fhews how much of that particular gas was prefent.

The firft inftrument of this kind, adapted to general purpofes, was invented by Dr. Hope, of which a defcription will be found under EUDIOMETRY. Under the fame article will be found Mr. Davy's eudiometer for the analyfis of the atmofphere.

Mr. Pepys has lately invented a very good eudiometer: it differs from Dr. Hope's in the bulb, which holds the abforbing liquid, being an elaftic gum bottle inftead of glafs. A glafs neck is tied into the neck of the bottle, into which the graduated tube is ground. When this eudiometer is ufed, the elaftic bottle is filled with the abforbing liquid (lime water, for inftance), and the tube filled with the gas under examination (fuppofed to be carbonic acid), introduced into the neck.

On agitating the liquid to mix it with the gas, as the abforption goes on, the elaftic bottle collapfes, by the atmofpheric preffure, and the liquid occupies the place of the abforbed gas in the tube.

The only objection to this eudiometer is its want of flexibility, and this varying under different circumftances, fo that the denfity of the contained air can never be accurately known. The writer of this article has done away the above objection, by ufing a bag of oiled filk inftead of this elaftic gum bottle. The filk muft be very well coated, and the coating completely dry.

The eudiometer of Volta, which is found very ufeful in the prefence of the electric machine, is alfo called the *detonating jar*. It is ufed with oxygen to detect the prefence of hydrogen, and *vice verfâ*. This inftrument, *fig.* 22, confifts of a very thick glafs tube A B, having two bits of metal *a, b*, paffing into the tube oppofite to each other, the inner ends being feparated from each other a fmall diftance, fo that an electric fpark paffing between them, may be capable of inflaming hydrogen with oxygen.

The gas to be examined is introduced into this jar, and the electric fpark paffed through it. If hydrogen and oxygen be prefent, in fufficient quantity, they will explode, forming water, and producing a diminution of volume equal to the original bulk of gafes which have entered into combination. In the explofion of thefe gafes the water or mercury is apt to be thrown in various directions by the concuffion. We are indebted to Mr. Pepys for an ingenious method of preventing this evil. The tube A B is fecured to the iron ftand D E by means of a focket C. D is an iron tube containing a fpiral fpring, fimilar to that of the fpring *fteel-yard*. The rod *d*, which acts upon the fpring, is faftened to the foot E, which is fo heavy as not to be raifed by the force exerted upon the fpring. When the detonation of the gafes takes place, the force is exerted equally upon the inftrument and the liquid, in which it is immerfed, when they are both at liberty. Inftead of being all exerted upon the latter, it caufes the tube to rife, the fpring in the focket D giving way, and thus prevents the liquid from being difperfed. All the gafeous bodies containing hydrogen can now be analyfed by this inftrument. Dr. Henry has difcovered that ammonia, which does not appear combuftible, can be exploded with oxygen: its hydrogen forming water with that fubftance. See EUDIOMETRY.

Evaporating Veffels.—Thefe are of metal, earthen-ware, and glafs. They are generally made broad and fhallow, as feen in *fig.* 23, in order to expofe a greater evaporable furface. During the evaporation of any liquid, a current of air fhould conftantly be paffing over its furface. This object can be eafily attained by placing the veffel under the mouth of a chimney into which there is a confiderable draught. By this means alfo the vapour is prevented from coming into the room.

Thefe veffels are of filver for expelling the water from alkalis, and of glafs, or Wedgewood ware, for acids and fome folutions of falts.

Sand and Water Baths.—The fand bath, although fuperfeded by the Argand lamp, for diftillations in the fmall way, is, neverthelefs, very ufeful for digefting fubftances fubjected to folution, and for evaporation. Its heat is much more regular than the naked fire, but it may fometimes be too

hot for fubftances which are liable to be decompofed, fuch as infufions of vegetable or animal matters. The moft ufeful fand bath is made of a plate of caft iron, under which the flame of a fire plays, and a rim of caft or wrought iron laid upon it and filled with fine Calais fand.

A fand-bath frequently confifts of an iron difh or pan made to fit the mouth of a furnace. See FURNACE.

When an uniform heat, not higher than 212° of Fahrenheit, is required, or when it will be fufficient, the water bath is found highly ufeful. Inftead, however, of placing the fubftance to be heated in a veffel of boiling water, which was formerly the cafe, the bath may be heated with fteam at any diftance from the boiler. This bath may be a veffel of any fhape, having a cavity for fteam on the outfide, thickly covered with flannel, or any bad conductor of heat, and the infide filled with fand. This bath is admirably fitted for the evaporation of folutions of animal and vegetable fubftances, and for drying precipitates and other fubftances liable to be decompofed or changed by great heat.

Mattras.—This is a veffel ufed for making folutions of fubftances. It is generally of a fpherical form, flattened at the bottom, as feen in *fig.* 24, having a long neck to allow the fluid to condenfe and return into the veffel. This ufeful apparatus is made of glafs, and thin at the bottom, in order to prevent its breaking. The common Florence flafk is a good fubftitute for the mattras. A fmaller veffel of this kind is ufed for boiling a lefs quantity of any liquid; thefe are called *proof glaffes*. See *fig.* 25.

Precipitating Glaffes.—See *fig.* 26.—Thefe are tall cylindrical veffels, in which precipitations are performed, in order to collect the feparated matter into lefs room. In wafhing precipitates it is found, that when hot water is poured into the glafs, if the bottom be thick it is liable to break. This evil has exifted more or lefs in all the precipitating glaffes in general ufe. In making this veffel at the glafs-houfe, the part to form the bottom fhould be blown out thin, like the mattras, and then pufhed inwards to make it ftand firmly. Very fmall veffels in this fhape are ufed for fmall quantities of any fubftance. Thefe are called *teft glaffes*.

Gas bottles, fuch as *fig.* 27, are veffels for obtaining hydrogen, carbonic acid, and other gafes. The materials, fuch as water and zinc filings, are introduced into the bottle A. The fulphuric acid being put into the bottle B, the plug *b*, which is ground into the neck *d*, can be raifed to let in the acid as it may be wanted. The gas efcapes through the crooked tube C, which may be put under the fhelf of the pneumatic trough.

Funnels are ufed generally for filtration; they are commonly, and always ought to be ribbed for this purpofe, in order to form channels between the paper and the glafs, which greatly facilitates the procefs. In lieu of a ribbed filter, it is common to place a number of ftraws, or pieces of glafs, between the paper and the veffel, which anfwers very well.

The feparatory funnel, *fig.* 34, is ufed for feparating fluids, fuch as water and oil, which do not mix from the difference in fpecific gravity.

The following articles are alfo effential to the laboratory, which it will be unneceffary to defcribe.

Thermometers and a barometer. Bottle for afcertaining the fpecific gravity of liquids.

A common ftill to furnifh diftilled water.

A fmall one of filver for nice purpofes.

The different blow-pipe apparatus, with platina, fpoon, and leaf platina.

A filver crucible, and one of platina.

Crucibles and crucible ftands of earthen ware. See *figs.* 29, 30, and 32.

Muffels and cupels. See *figs.* 28 and 33.

Iron retort and jointed tube for procuring oxygen gas. *Fig.* 35.

Glafs jars of different fizes for collecting gafes.

Filtering paper, and papers coloured with litmus, turmeric, and red-cabbage.

A general affortment of glaffes, to filter liquids into, &c.

An affortment of earthen veffels for common purpofes. Thofe made of the fame materials as the foda water bottles are to be preferred.

Capfules of glafs, and watch-glaffes. The former may be cut out of broken retorts and receivers with a fmall hot iron.

Glafs tubes of different fizes, and a fpirit lamp for bending them.

Glafs and porcelain rods and fpoons for ftirring acids, &c.

Jars of glafs and earthen ware, with grooves round the top, for luting them clofely from the air. Thefe fhould be ufed for containing falts in cryftals.

Ruled paper for labels; copal varnifh to cover the fame, to keep off the dampnefs and fumes of acids.

Sheets and wires of different metals.

Silk and thread of different ftrength.

Stands made of wood or rufhes, for fupporting veffels with round bottoms.

Iron ladles of different fizes.

Hammers, fhears, and plyers.

Corks, bladders, and fponge.

Tongs of various forms.

Files, diamond, and magnet.

Lutes, linen, cloth, and tow. See LUTE.

The following philofophical apparatus;

Air-pump for condenfing and exhaufting.

Syringes, microfcope, and burning-lens.

Electric machine and Galvanic apparatus.

Zinc plates and wire, for minor experiments.

Hydroftatic balance and hydrometer.

We fhall conclude this article with a lift of the chemical fubftances neceffary to be kept in a chemical laboratory. Thefe are divided into wet and dry fubftances. The firft of thefe muft, of neceffity, be kept in well-ftopped bottles. The latter fhould alfo be kept in bottles, the necks of which fhould be wider than thofe for liquids.

Subftances in common ufe fhould be kept in larger quantity than thofe which are kept as mere fpecimens, or only ufed occafionally and in fmall quantity.

Liquids in common Ufe.

Sulphuric acid, pure.
——— ——— common.
Nitric acid, pure.
————, common.
Muriatic acid, pure.
——— ———, common.
Acetic acid.
Water faturated with ammonia.
Solution of potafh.
———— carbonat of potafh.
———— potafh.
———— fuper-carbonat of potafh.
-- foda, and carbonat of foda.
carbonat of ammonia.
Lime water.
Diftilled water.

Alcohol, pure.
———, common.

The bottles in which the above are kept ſhould hold from a pint to a quart each.

After a change of temperature in the air from cold to hot, we find at the tops of bottles, about the ſtopper, a quantity of the liquid which has diſtilled up to the ſtopper, and been forced out by the expanſion of the air in the bottle. This is very troubleſome, eſpecially with acids, and may be remedied by giving to the mouth of the bottle a ſlight funnel ſhape, which forms a receſs for the liquid.

The following are the dry ſubſtances in common uſe.

Oxyd of mangaueſe, and common ſalt.
Filings and rods of iron, tin, zinc, copper, and lead.
Chalk and powdered marble.
Quick lime, pipe clay, and ſand.
Magneſia, common and calcined.
Sulphurets of potaſh, iron, and lime.
Iſinglaſs and nutgalls.
Brazil wood and turmeric.
Calcined plaſter of Paris, and bone aſhes.
Black flux and white flux, See FLUX.
Charcoal powder and ſaw-duſt.
Sulphat of lead, as a body for lutes.
Nitre in cryſtals.
Borax and alum.

The following are bodies in ſolution, uſed as teſts and kept in ſmall quantities, in bottles from one to two ounces in ſize. The bottles ſhould be ſhaped at the mouth as above recommended, and the diameter ſhould be half the height in the cylindric part.

Sulphat of potaſh.
ſoda.
alumine.
ammonia.
magneſia.
zinc.
ſilver.
Oxy-ſulphat of iron.
Nitrat of potaſh.
——— ſoda.
——— barytes.
——— ſtrontian.
——— lime
——— ſilver.
——— copper.
——— lead.
——— biſmuth.
Muriat of potaſh.
——— ſoda.
——— barytes.
——— ſtrontian.
——— lime.
——— ammonia.
——— gold.
——— platina.
tin.
cobalt.

Oxymuriat of mercury.
Phoſphat of ſoda.
——— ammonia.
Fluat of potaſh.
——— ammonia.
Borat of ſoda.
Carbonat of potaſh.
——— ſoda.
——— ammonia.
Acetat of potaſh.
——— barytes.
——— ſtrontian.
alumine.
ſilver.
——— copper
——— lead.
Oxyacetat of iron.
Oxalat of ſoda and ammonia.
Succinat of ammonia.
Tartrat of ammonia.
Pruſſiat of potaſh and iron.
——— lime and iron.
Pure gallic acid in alcohol.
Infuſion of galls in alcohol.
——— of litmus.
Acetic acid, pure.
Hydroſulphuret of potaſh.

The following ſubſtances ſhould be kept in the ſolid ſtate, and free from the contact of air and moiſture.

Sulphat of iron kept in alcohol.
Muriat of lime.
Oxymuriat of potaſh.
Barytic earth.
Strontian earth, and all pure earths.
Pure potaſh.
——— ſoda.

Potaſſium and ſodium, kept in naphtha. See POTASSIUM and SODIUM.

Sulphurets of potaſh, iron, and lime.
Phoſphuret of lime.
Phoſphorus.
Pyrophorus.

It is alſo proper that the chemiſt ſhould poſſeſs as great a variety of all the known chemical bodies as poſſible, both ſimple and compound. They are worth poſſeſſing even as a matter of curioſity. But they will be highly valuable in giving a familiar knowledge of the different ſubſtances which the experimentaliſt may expect to meet with, and enable him to diſtinguiſh them from what may be new.

Lac

LAC, or LACCA, *Gum*, as it is commonly, though not very properly, denominated, becaufe it is neither a gum nor a refin, is a kind of compound fubftance, prepared by the female of a minute infect, called by fome COCCUS *Lacca*, and by others CHERMES *Lacca*, which is found in feveral fpecies of trees in the Eaft Indies, and particularly on the banyan-tree (Ficus indica and religiofa of Linnæus), feveral fpecies of Mimofa, and the Biher on Rhamnus jujuba. Thefe infects are nourifhed by the trees on which they are produced, and fix themfelves upon the fucculent extremities of the young branches; and around their edges they are environed with a fpiffid fub-pellucid liquid, which feems to glue them to the branch. It is the gradual accumulation of this liquid, which forms a complete cell for each infect, and is what is called Gum Lacca. When the cells are completely formed, the infect is in appearance an oval, fmooth, red bag, without life, about the fize of a fmall cochineal infect, emarginated at the obtufe end, full of a beautiful red liquid. When the eggs are hatched, the young infects, or grubs, firft feed upon the red liquid above-mentioned, and when this is expended, they pierce a hole through the coat that invefts them, and move off one by one, leaving their exuviæ behind, which are the white membranous fubftance found in the empty cells of the Stick lac. The accumulation of lac appears in the economy of this infect to be the fubftance that anfwers the double purpofe of a nidus and covering to the egg or infect in the firft ftage of its exiftence, and of food for the maggot in its more advanced ftate. The lac is formed into complete cells, finifhed with as much regularity and art as the honey-comb, but differently arranged. The flies are invited to depofit their eggs on the branches of the trees by befmearing them with fome of the frefh lac fteeped in water, which attracts the fly, and gives a better and larger crop. For a particular defcription of thefe infects, and their cells, we refer to the papers of Mr. James Keir, of Patna; Mr. Robert Saunders, furgeon, at Boglepoor, in Bengal; and Dr. Roxburgh, of Samulcotta, in the Philofophical Tranfactions, vols. lxxi. lxxix. and lxxxi. Lac is a ftaple article of commerce in Affam, a country bordering on, and much connected with, Thibet, which furnifhes the greateft quantity of that in ufe; and it is alfo found upon the uncul-

tivated mountains on both sides of the Ganges. The only trouble in procuring it is that of breaking down the branches, and carrying them to market. The price in Dacca, in 1781, says Mr. Kerr, was about 12*s*. the hundred pounds weight, although it was brought from the distant country of Assam. The best lac is of a deep red colour. If it is pale, and pierced at top, it is depretiated in value, because the insects have left their cells, and consequently they can be of no use as a dye or colour; though they may be probably better for varnishers. Of lac there are four kinds known in commerce: *viz.* 1. *Stick* lac, which is the lac in its natural state, from which all the others are formed. This is obtained in pretty considerable lumps, with much of the woody parts of the branches on which it is formed adhering to it. 2. *Seed* lac, which is the former broken into small pieces, garbled, and appearing in a granulated form. 3. *Lump* lac, which is *seed* lac liquefied by fire, and formed into cakes. 4. *Shell* lac is the purified lac, or the cells liquefied, strained, and formed into their transparent laminæ. Lac is brought into this state, or purified, by the following process. It is broken into small pieces, and picked from the branches and sticks, and then put into a sort of canvas bag of about four feet long, and about six inches in circumference. Two of these bags are in constant use, and each of them held by two men. The bag is placed over a fire, and frequently turned till the lac is liquid enough to pass through its pores, when it is taken off the fire, and squeezed by two men in different directions, dragging it along the convex part of a plantain tree (Musa paradisaica of Linnæus), prepared for the purpose: while this is doing, the other bag is heating, to be treated in the same manner. The mucilaginous and smooth surface of the plantain-tree seems peculiarly well adapted for preventing the adhesion of the heated lac, and giving it the form, which enhances its value so much. The degree of pressure on the plantain-tree regulates the thickness of the shell, and the quality of the bag determines its fineness and transparency, upon which its value depends.

The lac is applied to various purposes by the natives in India. A great quantity of the *shell* lac is consumed in making ornamental rings, painted and gilded in a variety of tastes, to decorate the arms of the ladies; and it is formed into beads, spiral and linked chains for necklaces, and other female ornaments. It is also used for sealing-wax. For this purpose, take a stick, and heat one end of it upon a charcoal fire; put upon it a few leaves of the shell lac softened above the fire; keep alternately heating and adding more shell lac, until you obtain a mass of three or four pounds of liquefied shell lac upon the end of your stick. Knead this upon a wetted board, with three ounces of levigated cinnabar, and form it into cylindrical pieces; and to give them a polish, rub them while hot with a cotton cloth.

For japanning, take a lump of shell lac, prepared in the manner of sealing-wax, with whatever colour you please, fix it upon the end of a stick, heat the polished wood over a charcoal fire, and rub it over with the half-melted lac, and polish by rubbing it even with a piece of folded plantain leaf held in the hand; heating the lacquer, and adding more lac as occasion requires. Their figures are formed by lac, charged with various colours in the same manner. In ornamenting their images and religious houses, &c. they make use of very thin beaten lead, which they cover with various varnishes, made of lac charged with colours. The preparation of them is kept a secret. The leaf of lead is laid upon a smooth iron heated by fire below, while they spread the varnish upon it.

For grindstones, take of river sand three parts, of seed lac washed one part, mix them over the fire in a pot, and form the mass into the shape of a grindstone, having a square hole in the centre, fix it on an axis with liquefied lac, heat the stone moderately, and by turning the axis it may be easily formed into an exact orbicular shape. Polishing grindstones are made only of such sand as will pass easily through fine muslin, in the proportion of two parts of sand to one of lac. The sand is composed of small angular crystalline particles, tinged red with iron, two parts to one of black magnetic sand. The stone-cutters, instead of sand, use the powder of a very hard granate, called Corunde. These grindstones cut very fast: when they want to increase their power, they throw sand upon them, or let them occasionally touch the edge of a vitrified brick. The same composition is formed upon sticks; for cutting stones, shells, &c. by the hand.

For painting, take one gallon of the red liquid from the first working for shell lac, strain it through a cloth, and let it boil for a short time, then add half an ounce of fossil alkali; boil an hour more, and add three ounces of powdered load (bark of a tree), boil a short time, let it stand all night, and strain next day. Evaporate three quarts of milk, without cream, to two quarts, upon a slow fire, curdle it with some milk, and let it stand for a day or two, then mix it with the red liquid above-mentioned; strain them through a cloth, add to the mixture 1½oz. of alum, and the juice of eight or ten lemons; mix the whole, and throw it into a cloth-bag strainer. The blood of the insect forms a coagulum with the caseous part of the milk, and remains in the bag, while a limpid acid water drains from it. The coagulum is dried in the shade, and is used as a red colour in painting and colouring.

For dyeing, take one gallon of the red liquid prepared as before without milk, to which add three ounces of alum. Boil three or four ounces of tamarinds in a gallon of water, and strain the liquor. Mix equal parts of the red liquid and tamarind water over a brisk fire. In this mixture dip and wring the silk alternately, until it has received a proper quantity of the dye. To increase the colour, increase the proportion of the red liquid, and let the silk boil a few minutes in the mixture. To make the silk hold the colour, they boil a handful of the bark called load in water; strain the decoction, and add cold water to it; dip the dried silk into this liquor several times, and then dry it. Cotton cloths are dyed in this manner; but the dye is not so lasting as in silk. The lac colour is preserved by the natives upon flakes of cotton dipped repeatedly into a strong solution of the lac insect in water, and then dried. The Hindoos, as Mr. Charles Wilkins informed Mr. Hatchett, dissolve shell lac in water, by the mere addition of a little borax; and the solution, being then mixed with ivory-black, or lamp-black, is employed by them as an ink, which, when dry, is not easily acted upon by damp or water. Mr. Hatchett found this fact to be exactly as it was stated by Mr. Wilkins.

Besides the lac above-mentioned, there is another sort which is white or yellowish, brought from Madagascar, very much resembling the pe-la of the Chinese, which has been lately examined by Dr. Pearson. See Laccic *Acid*.

Mr. Hatchett (Phil. Transf. for 1804, part ii.), has detailed a number of experiments for the analysis of the three common species of lac, with a view of ascertaining its constituent parts and discriminating properties. *f.*

Lac, though long known in Europe, has not much attracted the attention of chemists. The first person who subjected it to a regular examination was the younger Geoffroy, the result of which is published in the Mem. de l'Acad. de Paris for 1714. He concluded that this substance is not, as some have supposed, a gum or resin, which

has exuded from vegetables simply punctured by insects. Geoffroy and Lemery obtained from lac, by distillation, some acid liquor, and a butyraceous substance; and Geoffroy observes, that when stick-lac was thus treated, some ammonia was also obtained, but not when seed-lac was employed. Geoffroy considered lac as a kind of wax, very distinct from the nature of gum or resin. Since his time it has been little examined, and therefore chemists have entertained various opinions concerning it. Chaptal, adopting Geoffroy's opinion, calls it a kind of wax; but Gren and Fourcroy regard it as a true resin.

Mr. Hatchett found that when water is poured on stick lac, reduced to powder, it immediately began to be tinged with red, and by heat, a deep-coloured crimson solution was formed. Repeated operations of this kind reduce stick-lac to a yellowish-brown substance, and the water no longer receives any colour. The portion separated from the lac has, on an average, amounted to 10 *per cent.*; but as it cannot be completely separated, considerable variations must be expected in different samples.

Fine seed-lac does not afford more than $2\frac{1}{2}$ or 3 *per cent.* of the colouring substance; and shell-lac, when treated in the same manner, *i. e.* merely with water, did not yield more than $\frac{1}{2}$ *per cent.* Alcohol dissolves a considerable portion of each of the different kinds of lac; and when heat is not employed, the dissolved part is resin, combined with some of the colouring matter; but if the lac is digested with heated alcohol, the solution is more or less turbid, and it is difficult to obtain it in a state of purity and transparency, either by repose or filtration. The solution obtained by digesting stick-lac in alcohol, without heat, is of a dark brownish-red colour; and the insoluble part subsides, retaining the greater part of the colouring matter, most easily soluble in water. The proportion of resin thus dissolved, when stick-lac is treated with alcohol, amounted to 67 or 68 *per cent.* The seed-lac used by Mr. Hatchett was very pure, and yielded to alcohol about 88 *per cent.* of resin, containing little of the colouring matter. Shell-lac, in small fragments, by simple digestion with alcohol, afforded in the first instance nearly 81 *per cent.*; but part of the resin required subsequent operations to separate it, so that the total quantity of resin might be estimated at 91 *per cent.* Sulphuric ether does not seem to act so powerfully upon the varieties of lac as alcohol; and, therefore, ether is not the best menstruum for lac. Concentric sulphuric acid acts first on the colouring matter of lac; and after a short digestion in a sand-bath, the whole is converted into a reddish-brown thick liquor, which soon becomes black; and the chief part of the lac is separated in an insoluble state, resembling coal. During the solution of lac in sulphuric acid, a considerable quantity of sulphureous acid gas is evolved. When lac is digested with nitric acid, nitrous gas is at first produced; the lac swells much, and is converted into a deep yellow opaque brittle substance, which, by a sufficiency of nitric acid, and a continuance of the digestion for about 48 hours, is dissolved.

This yellow nitric solution is converted by evaporation into a deep yellow substance, which burns like resin, but is soluble in boiling water. Muriatic acid dissolves the colouring matter and gluten of lac with a feeble action, unless the resin has been previously separated. Acetous acid much resembles the muriatic in its effects. Stick-lac, seed lac, and shell-lac are partially dissolved by acetic acid; and the dissolved part consists of the colouring extract of resin, and of gluten; the wax being the only ingredient which is insoluble in this menstruum. A saturated solution of boracic acid in water dissolves the colouring extract; but the lac is little, if at all, acted upon by this acid. Subborate of soda or borax has a powerful effect on lac, so as to render it soluble in water; and it is concluded from these facts, that the excess of soda in borax is the active substance, which conclusion is corroborated by experiments made with the alkalis. In order to render lac, especially shell-lac, soluble in water, about one-fifth of borax is necessary. The best proportion of water to that of lac is 18 or 20 to 1; so that 20 grains of borax, and 4 oz. of water, are, upon an average, requisite to dissolve 100 grains of shell-lac. The general properties of the solution shew, that it is a saponaceous compound, which, being used as a varnish, or vehicle for colours, becomes (when dry) difficultly soluble in water. The lixivia of pure soda, and of carbonat of soda, completely dissolve the several kinds of lac; and the solutions resemble those formed by means of borax, excepting that they are deeper coloured. Lixivium of pure or caustic potash speedily dissolves the varieties of lac, and forms saponaceous solutions, similar to that with borax, exclusive of the colour, which more approaches to purple. Lixivium of carburate of potash extracts a great part of the colouring matter, but less completely dissolves the entire substance of lac than pure potash. Pure ammonia, and carbonate of ammonia, readily act upon the colouring matter of lac, but do not completely dissolve the entire substance.

From a variety of other experiments, as well as those, the results of which we have given, but which we cannot recite, it appears that the different kinds of lac consist of four substances, namely, extract, resin, gluten, and wax. The extract, when dry, is of a deep red colour, approaching to purplish-crimson; emitting smoke when laid on a red-hot iron, with a smell like that of burned animal matter, and leaving a bulky porous coal; partially soluble in water, hot or cold; more slowly in alcohol, and with a less beautiful colour; insoluble in sulphuric ether; soluble in sulphuric, nitric, and acetic acid; partially in muriatic acid; not very readily in acetous acid; almost perfectly soluble in the lixivia of potash, soda, and ammonia, with a beautiful deep purple colour. When pure alumine is put into the aqueous solution, it does not immediately produce any effect, but with the addition of a few drops of muriatic acid, the colouring matter speedily combines with the alumine, and a beautiful lake is formed. A fine crimson precipitate is also produced by muriate of tin, when added to the aqueous solution: a similar coloured precipitate is also formed by the addition of solution of isinglass. These properties of the colouring substance of lac, especially its partial solubility in water and in alcohol, and its insolubility in ether, together with the precipitate formed by alumine and muriate of tin, indicate that this substance is vegetable extract, perhaps slightly animalized by the coccus.

The resin of lac is of a brownish-yellow colour, emitting on a red-hot iron much smoke, with a peculiar sweet odour, and leaving a spongy coal; completely soluble in alcohol, ether, acetic acid, nitric acid, and the lixivia of potash and soda; precipitated by water from alcohol, ether, acetic acid, and partially from nitric acid; and possessing the other general characters of a true resin.

The gluten is obtainable in two ways; if the pieces of lac, after digestion in alcohol, be digested with dilute acetic, or muriatic acid, most of the gluten is dissolved, and may be precipitated by alkalies, added in due proportion; but is redissolved by an excess of them, and then is separable by acids. It much resembles the gluten of wheat.

The wax of lac is found floating like oil on the surface of a solution of lac, after long and repeated digestion in boiling nitric acid, and may be collected when cold; or it may

be more eafily obtained in a pure ftate, by digefting the refidue left by alcohol in boiling nitric acid. The wax, thus obtained, when pure, is pale yellowifh-white, and (unlike bees' wax) is devoid of tenacity, and extremely brittle: it melts at a much lower temperature than that of boiling water, and burns with a bright flame, and an odour refembling that of fpermaceti. It is infoluble in water and cold alcohol; but the latter, when boiled, partially diffolves it, and upon cooling, depofits the greater part; foluble in heated fulphuric ether, but upon cooling, nearly the whole is depofited. Lixivium of potafh, boiled with the wax, forms a milky folution; but moft of the wax floats on the furface in the ftate of white flocculi, and appears to be converted into a kind of foap of difficult folubility; it is no longer inflammable; and, with water, forms a turbid folution, from which, as well as from the folution in potafh, the wax may be precipitated by acids. Ammonia, when heated, diffolves a fmall portion of the wax, and forms a folution fimilar to the former; nitric and muriatic acids do not act upon the wax. When the properties of this fubftance are compared with thofe of bees'-wax, a difference will be perceived; and on the contrary, the moft ftriking analogy is evident between the wax of lac and the myrtle wax which is obtained from the Myrica cerifera. The properties of myrtle wax, defcribed by Dr. Boftock in Nicholfon's Journal for March, 1803, coincide fo perfectly with thofe of the wax of lac, that Mr. Hatchett is led to confider them as almoft, if not altogether, the fame fubftance.

Our author, from his analyfis of the three different fpecies of lac infers, that the fubftances that compofe them bear the following proportions: 100 parts of ftick-lac gave 68 of refin, 10 of colouring extract, 6 of wax, 5.5 of gluten, and 6.5 of extraneous fubftances: 100 parts of feed-lac gave 88.5 of refin, 2.5 of colouring extract, 4.5 of wax, and 2 of gluten: 100 parts of fhell-lac gave 90.9 of refin, 0.5 of colouring extract, four of wax, and 2.8 of gluten.

We have already fpecified feveral ufes to which lac is applied in India, and it is no lefs important, in a variety of refpects in Europe. A folution of lac in water may be advantageoufly employed as a fort of varnifh, which is equal in durability, and other qualities, to thofe prepared with alcohol; and, of courfe, much cheaper. It will be found, likewife, of great ufe as a vehicle for colours; for, when dry, it is not eafily affected by damp, or even by water. Mr. Hatchett fays, that with a folution of this kind he has mixed various colours, fuch as vermilion, fine lake, indigo, Pruffian blue, fap-green, and gamboge; and it is remarkable, that although the two laft are of a gummy nature, and the others had been previoufly mixed with gum (being cakes of the patent water-colour), yet, when dried upon paper, they could not be removed with a moiftened fponge, until the furface of the paper itfelf was rubbed off. In many arts and manufactures, therefore, the folutions of lac may be found of great utility; for, like mucilage, they may be diluted with water, and yet, when dry, are little, if at all, affected by it.

The colour given by lac is lefs beautiful, but more durable than that given by cochineal. To render the colouring matter of the lac diffufible in water, fo as to be applied to the ftuffs to be dyed, Mr. Hellot directs the following procefs:—Let fome powdered gum-lac be digefted for two hours in a decoction of comfrey-root, by which a fine crimfon colour is given to the water, and the gum is rendered pale or ftraw-coloured. To this tincture, poured off clear, let a folution of alum be added; and when the colouring matter has fubfided, let it be feparated from the clear liquor, and dried. It will weigh about one-fifth of the quantity of lac employed. This dried fecula is to be diffolved or diffufed in warm water, and fome folution of tin is to be added to it, by which it acquires a vivid fcarlet colour. This liquor is to be added to a folution of tartar in boiling water; and thus the dye is prepared.

The method of obtaining the fine red lac ufed by painters from this fubftance, is by the following fimple procefs:—Boil the ftick-lac in water, filtre the decoction, and evaporate the clear liquor to a drynefs over a gentle fire. The occafion of this eafy feparation is, that the beautiful red colour, here feparated, adheres only flightly to the outfides of the fticks, broken off the trees along with the gum-lac, and readily communicates itfelf to boiling water. Some of this fticking matter alfo adhering to the gum itfelf, it is porper to boil the whole together; for the gum does not at all prejudice the colour, nor diffolve in boiling water: fo that after this operation the gum is as fit for making fealing-wax as before, and for all other ufes which do not require its colour. See LAKE.

A tincture of gum-lac may thus be prepared:—Take two ounces of gum-lac, reduce it to a fine powder, and make it into a ftiff pafte with oil of tartar *per deliquium*; fet this in an open glafs to dry by a gentle heat, then remove it to the open air, that it may relent and grow foft; then dry it again, and repeat this two or three times, at the end of which the hard body of this refin will be found refolved into a purple colour. This may yet again be dried, and when dried muft be reduced to powder, which powder will afford a fine ftrong tincture to fpirit of wine, being boiled in it in a tall glafs in a fand-heat for two or three hours. And by this procefs ftrong tinctures may be made from myrrh, amber, gum, juniper, &c. which will yield no tincture of ftrength to fpirit of wine alone, if treated in the ufual way.

A fpirituous tincture of ftick-lac was formerly fometimes given as a mild reftringent and corroborant in female weakneffes, and in rheumatic and fcorbutic diforders. But the principal medicinal ufe of this concrete was as a topical corroborant and antifeptic, in laxities and fcorbutic bleedings, and exulcerations of the gums. Some employed for this purpofe a tincture of the lac in alum water; others a tincture made in vinous fpirits, impregnated with the pungent antifcorbutics. The college of Edinburgh directed an ounce of the powdered lac, with half an ounce of powdered myrrh, to be digefted in a fand-heat, for fix days, in a pint and a half of fpirit of fcurvy grafs.

The gum-lac has been lately ufed as an electric, inftead of glafs, for electrical machines. See LACQUER, LAKE, and VARNISH.

LAC, or LACCA, *Ammoniaci*, in the *Materia Medica*. See *Gum* AMMONIAC.

LAC, or LACCA, *Artificial*, or LAQUE, is alfo a name given to a coloured fubftance, drawn from feveral flowers; as the yellow from the flower of the juniper, the red from the poppy, and the blue from the iris or violet.

The tinctures of thefe flowers are extracted by digefting them feveral times in aqua vitæ, or by boiling them over a ftove fire in a lixivium of pot-afhes and alum.

An artificial lacca is alfo made of Brazil wood, boiled in a lixivium of the branches of the vine, adding a little cochineal, turmeric, calcined alum, and arfenic, incorporated with the bones of the cuttle-fifh pulverized, and made up into little cakes, and dried.

If it be to be very red, they add the juice of lemon to it; to make it brown, they add oil of tartar.

Dove-coloured, or columbine lacca, is made with Brazil of Fernambuc, fteeped in diftilled vinegar for the fpace of a

month, and mixed with alum incorporated in cuttle-fish bone. For other processes, see LAKE and MADDER.

LAC, *Acid of*. See LACCIC *Acid*.

LAC, or *Gum Lac*. See CROTON.

Lace

LACE, in the *Manufactures*, is formed of thread, cotton, or filk, woven into a net, the meſhes of which are varied in their figure, according to the deſign of the pattern, as octagons, hexagons, &c. &c. The lace is alſo ornamented by a thread, much thicker than the thread forming the net, which is woven in among the meſhes, in the figure of flowers, and other fantaſtic curves; upon the beauty and elegance of which, the value of the lace depends. This thick thread is called the *gimp*.

Lace is made upon a pillow or cuſhion, upon which a piece of ſtiff parchment is ſtretched, having a number of holes pricked through it, to form a pattern of the intended lace. Through theſe holes, pins are ſtuck into the pillow; and the threads, wound upon ſmall bobbins, are woven around the pins, and twiſted round each other in various ways, to form the required pattern. This proceſs is extremely tedious, particularly for the wide laces, with complicated patterns; and though it is extremely expenſive to the conſumer, the people (chiefly in Bedford and Buckinghamſhire) who manufacture it can only obtain ſufficient to ſupport a wretched exiſtence, by the moſt inceſſant exertion. Of late years, the manufacturers of Nottingham have directed their ingenuity to imitate this ſpecies of lace by machinery, in which they have ſucceeded moſt perfectly: but ſtill it is only an imitation, the knot or loop of the meſhes being eſſentially different. In the pillow lace, the net or meſhes may be deſcribed, by ſuppoſing a number of ropes, each formed of two or more threads twiſted round each other: theſe are extended parallel; but at every two or three ſpiral turns of theſe ropes, the ſtrands or threads compoſing one rope are twiſted around with thoſe of its neighbour, and then return to be twiſted with its own: and this reciprocally of the whole number forms a netting; the figure of the meſhes depending upon the number of turns which are made, before the twiſt is changed from one rope to the next. To form a lace of this deſcription, it is eſſential that

the ends of each thread be detached, and capable of being twisted over the adjacent threads. This is easily done by the hand upon the pillow, by twisting the bobbins round each other; but has many difficulties which prevent its performance by machinery.

The Nottingham lace is only a modification of the stitch or loop of which stockings are made; all the meshes being formed by a continuance of one thread, which is, by the machine, formed into loops a whole course (that is, length of the intended piece of lace) at once, by pressing it down alternately over and under between a number of parallel needles; a second course is then made of similar loops on the same needles, and the loops of the first are drawn through those of the second, in such a manner as to form meshes by retaining the first loops; the second are then retained by a third course, and this by a fourth, and so on. The machine is very nearly like a common stocking-frame, but provided with an additional apparatus, which can be readily applied. It consists of a frame, containing a number of needles, which we will call points; these are introduced between the fixed needles of the stocking-frame, and a certain number (one half, for instance) of the loops in the thread are taken off the fixed needles upon these points, which are moved endways, the space of two, three, or more fixed needles, and put down upon them again. Another set of loops is now taken upon the points, and moved in the opposite direction; by this means, crossing the loops over each other, and forming meshes, the figure of which will depend upon the number of needles it is thus carried over. But as this admits of no great variety of patterns, another machine has been invented, which is much more extended in its applications. Like the former, it has the parts of the stocking-frame, but differently made. The thread is, in this, rolled upon a cylinder, in the same manner as a weaver's beam; as many threads being wound round it as there are needles in the frame. These threads pass through eyes in the ends of small points, called guides, which are opposite the needles; and these guides are fixed on two bars, each of which has half the guides fastened in it, that is, one guide is fast in one bar, and the next in the other, and so on alternately of the whole. Each of the guides presents a thread to its needle, and are all at once moved by the hand to twist the threads two or three times round the needles which are opposite them: the loop is now made in a manner similar to the other frame. The next time, the alternate guides are shifted endways, so as to apply themselves to other needles than those they were opposite before. This crosses the thread, so as to make a net: but the quantity which is shifted endways is altered every time, by means of the machinery, so as to move a certain number of needles; which number is altered every time, to produce the pattern. All the parts of this machine, except the guides, are moved by means of treadles, instead of using the hands, as in the common stocking-frame. The net produced by these frames is woven in bands of the width of the intended lace, leaving a wider mesh than the others, through which the division is to be made to separate the lace into narrow strips. Before cutting up in this manner, the lace is spread in a frame, and a common needle with a thick thread is worked in the meshes, to imitate the gimp, according to the pattern for which the lace is intended.

The lace trade of Nottingham has been carried to a very great extent, but is at present in a state of stagnation, being chiefly dependent on foreign trade, as it has never been in such great repute with the British ladies.

Lace is also made of *gold* and *silver thread* (which see), much in the same manner as the bone or blond lace above described. The importation of gold and silver lace is prohibited. Great quantities of the finest blond laces have been imported from Flanders. By 3 Geo. III. c. 21. and 5 Geo III. c. 48. if any person shall import any ribbands, laces, or girdles, not made in Great Britain, whether the same shall be wrought of silk alone, or mixed with other materials, the same shall be forfeited, and may be seized by any officer of the customs, in whatever importers', venders', or retailers' hands they may be found; and the importer, and every person assisting therein, and the venders and retailers in whose custody they shall be found, or who shall sell or expose the same to sale, or conceal with intent to prevent the forfeiture, shall forfeit respectively 200*l.* with costs; half to the king, and half to the officer who shall inform and prosecute.

Lace is also used for a kind of chord made of silk or cotton, chiefly used in lacing women's stays.

Lacquer

LACQUER, or LACKER, is a varnifh applied upon tin, brafs, and other metals, to preferve them from tarnifhing, and to improve their colour. The bafis of lacquers is a folution of the refinous fubftance called feed-lac, or rather fhell-lac, in fpirit of wine. This fpirit ought to be very much dephlegmated in order to diffolve much of the lac. For this purpofe, fome authors direct dry pot-afh to be thrown into the fpirit. This alkali attracts the water, with which it forms a liquid that fubfides diftinctly from the fpirit at the bottom of the veffel. From this liquid the fpirit may be feparated by decantation. By this method the fpirit is much dephlegmated: but at the fame time it becomes impregnated with part of the alkali, which depraves its colour, and communicates a property to the lacquer of imbibing moifture from the air. Thefe inconveniences may be prevented by diftilling the fpirit; or, if the artift has not an opportunity of performing that procefs, he may cleanfe the fpirit in a great meafure from the alkali, by adding to it fome calcined alum, the acid of which uniting with the alkali remaining in the fpirit, forms with it a vitriolated tartar, which, not being foluble in fpirit of wine, falls to the bottom together with the earth of the decompofed alum. To a pint of the dephlegmated and purified fpirit, about three ounces of powdered fhell-lac are to be added; and the mixture to be digefted during fome days with a moderate heat. The liquor ought then to be poured off, ftrained, and cleared by fettling. This clear liquor is now fit to receive the required colour, from certain refinous colouring fubftances, the principal of which are gamboge and anotto, the former of which gives a yellow, and the latter an orange colour. In order to give a golden colour, two parts of gamboge are added to one of anotto; but thefe colouring fubftances may be feparately diffolved in the tincture of lac, and the colour required may be adjufted by mixing the two folutions in different proportions. When filver-leaf, or tin, are to be lacquered, a larger quantity of the colouring materials is requifite than when the lacquer is intended to be laid on brafs.

There are fundry other materials, from a due mixture of which a like colour may be produced, as turmeric, faffron, dragon's blood, &c. See *Gold Coloured* VARNISH, and *Japanner's* GILDING.

Inftead of fhell-lac, ufed in the compofition of varnifhes for lacquering, refin or turpentine is fubftituted for the coarfer ufes. The following compofition for brafs-work, defigned to refemble gilding, has been much recommended: take of turmeric ground, as it may be had at the dry-falters, one ounce, and of faffron and Spanifh anotto each two drams: put them into a bottle with a pint of highly rectified fpirit of wine, and place the bottle in a moderate heat, occafionally fhaking it, for feveral days; then ftrain off the yellow tincture thus obtained, through a coarfe linen cloth, and putting it back into the bottle, add three ounces of good feed-lac grofsly powdered; place the bottle again in a moderate heat and fhake it, till the feed-lac be diffolved. The lacquer ftrained as before will be fit for ufe, and muft be kept in a bottle carefully ftopped. By increafing or diminifhing the proportion of anotto, the lacquer will be rendered warmer and redder, or cooler and nearer a true yellow. A cheaper compofition little inferior to the former, may be formed of one ounce of turmeric root ground, half a dram of the beft dragon's blood, and a pint of fpirit of wine, managed as the former.

The varnifh for tin may be made of one ounce of turmeric-root, two drams of dragon's blood, and one pint of fpirit of wine, prepared in the fame manner with the other. The dragon's blood may be increafed or diminifhed, as the red or yellow is to be the moft prevalent; and for a coarfer lacquer the quantity of fhell-lac may be leffened, and the deficiency fupplied by the fame proportion of refin. The lacquer for locks, nails, &c. where little or no colour is defired, may be either fhell-lac varnifh alone, or with a little dragon's blood; or a compound varnifh of equal parts of fhell-lac and refin, with or without the dragon's blood. The manner of laying on the lacquer is as follows: the pieces to be lacquered muft firft be made thoroughly clean; and if they be new founded, aquafortis muft be ufed for this purpofe. When they are afterwards heated by a fmall charcoal fire, the lacquer is laid on with a proper brufh, like other varnifhes, and the pieces reftored to the heat. After the lacquer is thoroughly dry and firm, the fame operation muft be renewed for four or five times, or till the work appears of the required colour and brightnefs.

The lacquering of leather, improperly called gilding, is performed by means of leaf-filver, coloured by a yellow varnifh. (See *Japanner's* GILDING.) For this purpofe calf or goat-fkins are procured in a dry ftate, after the common dreffing and tanning. They are foftened by being immerfed and ftirred about for fome hours in a tub of water; and afterwards beaten againft a flat ftone and fmoothed, by fpreading them on the ftone and rubbing

them over with an iron inftrument: the fkins, thus prepared, are joined together in pieces of the dimenfions required; and then fized on the grain of the leather with a kind of foft glue, or ftiff fize, that anfwers to the gold-fize ufed in other kinds of gilding or filvering, prepared from parchment or glover's cuttings. The workman next proceeds to cover the whole furface of the fized fkin, before it be quite dry, with leaf filver, and with a fox's tail, made into the form of a ball at the end, fettles the leaves, by preffing and ftriking them; and clofes this operation with gently rubbing the whole furface with the tail. When the fkins are filvered, they are hung to dry firft on cords, and the drying is completed by putting them over a board joined together, with the filvered fide next the boards, where they muft be kept ftretched out by means of fome nails. They are then burnifhed with a flint burnifher, which operation is performed by fpreading the fkin even on a fmooth ftone, and fliding the burnifher backwards and forwards over every part of the fkin, with a confiderable degree of preffure. In fome manufactures the burnifhing is performed, by paffing the filvered fkins betwixt two cylindrical rollers of fteel, with polifhed faces. The fkins are now prepared for receiving the yellow lacquer or varnifh, which gives the appearance of gilding. Different artifts have different recipes for compounding this lacquer. The following is faid to be equal to any hitherto ufed: take of fine white refin, 4½ pounds; the fame quantity of common refin; of gum fandarac, 2½ pounds; and of aloes, two pounds: bruife and mix them; and put them into an earthen pot over a good fire of charcoal, or over any other fire which has no flame: when all the ingredients are perfectly melted and mixed, add gradually to them feven pints of linfeed oil, and ftir the whole well together with a fpatula: let the whole boil, ftirring all the time, to prevent a kind of fediment, that will form, from fticking to the bottom of the veffel. When the varnifh is almoft fufficiently boiled, which will generally require feven or eight hours, add gradually half an ounce of litharge, or half an ounce of red lead; and when this is diffolved, pafs the varnifh through a linen cloth, or flannel bag. A pint of oil, and a correfponding proportion of fine refin and aloes, have produced a very good varnifh in an hour and a half. This lacquer or varnifh is laid on the filvered leather in the open air; and is beft done in fummer, when it is hot and dry. For this purpofe, the fkins are ftretched and faftened with nails to the boards, on which the drying was finifhed, with the filvered fide outwards. And when thefe boards are properly difpofed on treffels, the workman generally fpreads fome white of eggs over each fkin; and when this is dry, the varnifh, which is nearly of the confiftence of a thick fyrup, is repeatedly fpread with the four fingers of one hand, moved fo that each finger paints a kind of S with the varnifh, from one end of the fkin to the other: and it is then diffufed evenly over every part with the flat of the hand: after this it is to be immediately beaten by ftrokes of the palms of the hands, and principally where the varnifh is obferved to lie thickeft. When this coat of varnifh is fufficiently dry, which may be known by the fingers making no impreffion upon it, another coat is laid on in the fame manner. When this coat is dry, the varnifhing for producing the appearance of gilding is completed; and if it has been well performed, the leather will have a very fine gold colour, with a confiderable degree of polifh or brightnefs. When there is an intention to have one part of the leather filver, and the other gold, a pattern is formed on the furface, by printing, calking or ftamping, a defign on the furface after the filvering. The fkin is then to be varnifhed, as if the whole were intended to be gold; but after the laft coat, inftead of drying the varnifh, it is to be immediately taken off that part, which is intended to be filver, according to the defign printed or calked upon it, by a knife; with which the workman fcrapes off all that he can without injuring the filver, and afterwards by a linen cloth, with which all that remains is to be wiped or rubbed off. The fkins thus filvered and varnifhed, are made the ground of various defigns for emboffed work and painting. The emboffed work or relief is raifed by means of printing with a rolling prefs, fuch as is ufed for copper-plates; but the defign is here to be engraved on wood. The painting may be of any kind; but oil is principally ufed, as being durable and more eafily performed. Doffie's Handmaid to the Arts, vol. i. p. 454, &c.

Lake

LAKE, or LAQUE, a preparation of different fubftances into a kind of magiftery for the ufe of painters, dyers, &c. One of the fineft and firft invented of which was that of *gum lacca* or *lacque;* from which all the reft, as made by the fame procefs, are called by the common name *lacques*. See LAC or LACCA.

We may obſerve more generally, that all vegetable colours, which are ſoluble in water, are found to have a certain degree of affinity for ſome earths and metallic oxyds. Theſe combinations are called lakes. Thus, if a ſolution of alum is added to an infuſion of madder, a mutual decompoſition takes place, and part of the alumine falls down intimately united with the colouring matter of the madder: the ſeparation is much aſſiſted by the alkali. They are chiefly of two colours only, red and yellow: the red owing their colour to madder, Braſil wood, or cochineal; and the yellow to the different yellow infuſions uſed in dyeing. Both are generally uſed for water colours, and in oil painting as tranſparent colours. Theſe pigments are almoſt invariably compoſed either of alum, or ſometimes the ſolution of tin, and ſome other watery ſolution of a colouring matter.

Of the red lakes, that made with cochineal is the moſt beautiful, and of the greateſt value. It is called *carmine*, from its being applied to imitate the colour of the fleſh. For the method of preparing it, ſee COCHINEAL. See alſo CARMINE.

On the receipt for making carmine, introduced under the article COCHINEAL, a correſpondent has made the following obſervation.

The carbonat of ſoda and alum, added in the firſt inſtance, would be mutually decompoſed, and the alumine, with the colouring matter, would be precipitated with the dregs, which are afterwards ſeparated from the clear liquor; ſo that when the white of egg came to be added, the earth of the alum and a portion of the colouring matter, ſaid to be carried down by the albumen, cannot be preſent. Should the proceſs here given have any analogy to that which is practiſed, it would appear that the ſolution of cochineal in water has the white of egg added to it, in the firſt inſtance, if it is at all neceſſary, for the purpoſe of clearing the coloured ſolution, a property for which that ſubſtance is remarkable. That after the liquid becomes clear, and is ſeparated from the dregs, the carbonat of ſoda and alum are added, when a precipitate, conſiſting of the alumine united with the finer parts of the colouring matter, may be expected. The remaining colouring matter, which is of leſs beauty, is then uſed for the red lake.

Inſtead of uſing cochineal for making carmine, a much clearer colour may be extracted from the refuſe of ſcarlet cloth. The bits of cloth are boiled in a ſolution of potaſh, which extracts the colour, and holds it in ſolution. If to this a certain portion of alum be added, the colouring matter will be precipitated with the alumine, of a greater or leſs intenſity, proportionate to the quantity of this earthy baſis. In Doſſie's Handmaid to the Arts, we are told that the beſt of the lakes commonly ſold is made from the colour extracted from ſcarlet rags, and depoſited on the cuttle-bone; and that it may be prepared in the following manner: diſſolve a pound of the beſt pearl aſhes in two quarts of water, and filter the liquor through paper; add to this ſolution two more quarts of water, and a pound of clean ſcarlet ſhreds, and boil them in a pewter boiler, till the ſhreds have loſt their ſcarlet colour; take out the ſhreds and preſs them, and put the coloured water yielded by them to the other: in the ſame ſolution boil another pound of the ſhreds, proceeding in the ſame manner; and likewiſe a third and fourth pound. Whilſt this is doing, diſſolve a pound and a half of cuttle-fiſh bone in a pound of ſtrong aqua-fortis, in a glaſs receiver, adding more of the bone, if it appear to produce any ebullition in the aqua-fortis; and pour this ſtrained ſolution gradually into the other; but if any ebullition be occaſioned, more of the cuttle-fiſh bone muſt be diſſolved as before, and added, till no ebullition appears in the mixture. The crimſon ſediment depoſited by the liquor thus prepared is the lake: pour off the water, and ſtir the lake in two gallons of hard ſpring water, and mix the ſediment in two gallons of freſh water; let this method be repeated four or five times. If no hard water can be procured, or the lake appears too purple, half an ounce of alum ſhould be added to each quantity of water before it be uſed. Having thus ſufficiently freed the lake from the ſalts, drain off the water through a filter, covered with a worn linen cloth. When it has been drained to a proper dryneſs, let it be dropped through a proper funnel on clean boards, and the drops will become ſmall cones or pyramids, in which form the lake muſt be ſuffered to dry, and the preparation is completed.

Lakes are alſo made from madder and Braſil wood. The former is much more permanent than the latter, but does not poſſeſs the ſame beauty of tint. In order to make theſe lakes, ſtrong infuſions of theſe ſubſtances are firſt obtained. The Braſil wood infuſion is beſt made by boiling the chips in pure water, and filtering the ſolution. (See BRASIL *Wood*.) The infuſion of madder (ſee MADDER) is beſt made in cold water, by which the pureſt part of the colour is only diſſolved. To each of theſe ſolutions are added a clear ſolution of alum, and then as much of an alkali as will precipitate ſo much of the alumine as will make the colour of the precipitate of proper intenſity. A ſmall quantity of muriate of tin increaſes the brilliancy of theſe lakes.

A beautiful lake, it is ſaid (*ubi infra*), may be prepared from Braſil wood, by boiling three pounds of it, for an hour, in a ſolution of three pounds of common ſalt, in three gallons of water; and filtering the hot fluid through paper, add to this a ſolution of five pounds of alum in three gallons of water. Diſſolve three pounds of the beſt pearl aſhes in a gallon and a half of water, and purify it by filtering; put this gradually to the other, till the whole of the colour appear to be precipitated, and the fluid be left clear and colourleſs. But if any appearance of purple be ſeen, add a freſh quantity of the ſolution of alum by degrees, till a ſcarlet hue be produced. Then purſue the directions given in the firſt proceſs with regard to the ſediment. If half a pound of ſeed-lac be added to the ſolution of pearl aſhes, and diſſolved in it before its purification by the filtre, and two pounds of the wood, and a proportional quantity of the common ſalt and water be uſed in the coloured ſolution, lake will be produced that will ſtand well in oil or water, but it is not ſo tranſparent in oil as without the ſeed-lac. The lake with Braſil wood may be alſo made by adding half an ounce of anotto to each pound of the wood; but the anotto muſt be diſſolved in the ſolution of pearl aſhes. There is a kind of beautiful lake brought from China; but as it does not mix well with either water or oil, though it diſſolves entirely in ſpirit of wine, it is not of any uſe in our kinds of painting. This has been erroneouſly called ſafflower. Handmaid to the Arts, vol. i. p. 61, &c.

In making yellow lakes, the coloured infuſions muſt be ſuch as to make the moſt permanent dye. (See DYEING.) The precipitation of the colour is performed preciſely in the ſame way, and by the ſame ſubſtances, as the red lakes. A very excellent yellow lake may be made from the infuſion of *quercitron bark*. That from *turmeric* is very beautiful, but is not permanent. The proceſs for the making of this is as follows: take a pound of turmeric-root in fine powder, three pints of water, and an ounce of ſalt of tartar; put all into an earthen glazed veſſel, and let them boil together over a clear, gentle fire, till the water appears highly impregnated with the root, and will ſtain a paper to a beautiful yellow. Filtre this liquor, and gradually add to it a ſtrong ſolution of roch-alum in water, till the yellow matter is all curdled together, and precipitated; after this pour the whole into a

filtre of paper, and the water will run off and leave the yellow matter behind. It is to be washed many times with fresh water, till the water comes off insipid, and then is obtained the beautiful yellow, called *laque of turmeric*, and used in painting.

In this manner may a laque be made of any of the tinging substances that are of a somewhat strong texture, as madder, logwood, &c.; but it will not succeed in the more tender species, as the flowers of roses, violets, &c. as it destroys the nice arrangement of parts in those subjects, on which the colour depends.

A yellow lake for painting is to be made from broom-flower in the following manner: make a ley of pot-ashes and lime reasonably strong; in this boil, at a gentle fire, fresh broom-flowers till they are white, the ley having extracted all their colour; then take out the flowers, and put the ley to boil in earthen vessels over the fire; add as much alum as the liquor will dissolve; then empty this ley into a vessel of clear water, and it will give a yellow colour at the bottom. Let all settle, and decant off the clear liquor. Wash this powder, which is found at the bottom, with more water, till all the salts of the ley are washed off; then separate the yellow matter, and dry it in the shade. It proves a very valuable yellow.

All the lake colours are changed by acids and alkalies. An acid renders the red lake more scarlet, and the yellow paler; while an alkali gives a purple tint to the red, and an orange or brown tint to the yellow. Artists sometimes take advantage of this property to change their colours. The acid used for this purpose should be the muriatic diluted, and the alkali aqua ammonia.

Lake, *Orange*, is the tinging part of anotto precipitated together with the earth of alum. This pigment, which is of a bright orange colour, and fit for varnish painting, where there is no fear of flying, and also for putting under crystal to imitate the vinegar garnet, may be prepared by boiling four ounces of the best anotto and one pound of pearl-ashes half an hour in a gallon of water; and straining the solution through paper. Mix gradually with this a solution of a pound and a half of alum in another gallon of water; desisting, when no ebullition attends the commixture. Treat the sediment in the manner already directed for other kinds of lake, and dry it in square bits or round lozenges. Handmaid to the Arts, vol. i. p. 110.

Lambeth

LAMBETH, an extenſive pariſh, ſeated on the ſouthern bank of the river Thames, in the hundred of Brixton, and county of Surrey, England. It is directly oppoſite to Weſtminſter, to which city it is connected by a handſome ſtone bridge acroſs the river. The whole is bounded by Southwark to the eaſt, Newington Butts and Camberwell to the ſouth, and Batterſea to the weſt. The circumference is about 16 miles. In Domeſday-book, it is ſaid to contain 20½ plough-lands. At the beginning of the ſeventeenth century, it appears, by the churchwardens accounts, to have conſiſted of 1262 acres of arable land, 1026 of paſture, 125 of meadow, 13 of ozier, 27 of garden ground, and 150 of wood, making in the whole 2603; the commons and waſte land, ſuppoſed to be about 330 acres, not being charged, will increaſe it to 2933 acres. At preſent, the whole extent is about 4000 acres; of which about 1390 are occupied by houſes and other buildings, wharfs, manufactories, ſtreets, and roads; 415 by pleaſure gardens, including thoſe of Vauxhall; 80 by market gardens; 300 by farming gardens; 40 by nurſeries; 250 are now incloſing from common; and 30 are to remain common. The pariſh is divided into ſix liberties or precincts, reſpectively called the Biſhop's, the Prince's, Vauxhall, Marſh and Wall, Lambeth-Dean, and Stockwell; the whole containing, according to the return to parliament in the year 1800, 5009 houſes, and 27,985 inhabitants, of whom 5148 were ſtated to be employed in various trades and manufactures, and 955 in agriculture. Archbiſhop Hubert Walter obtained from king John a grant of a weekly market, and a fair of fifteen days, upon condition that the ſame ſhould not be detrimental to the intereſts of the city of London. In the archbiſhop's MS. library, is a charter from the city, ſignifying their conſent, ſtipulating only, that the fair ſhould begin on the morrow after the anniverſary of St. Peter ad vincula. The market and fair are both diſcontinued. The earlieſt hiſtorical fact on record relating to Lambeth, is the death of Hardicanute, which happened here in the year 1041, while he was celebrating the marriage feaſt of a noble Dane. Here alſo, Harold, who uſurped the throne on the death of Edward the Confeſſor, is ſaid to have placed the crown on his head with his own hands. Henry III. held a ſolemn Chriſtmas here in the year 1231; and a parliament on September 14, in the year following. A moſt violent outrage was committed in Lambeth church, on Sunday February 19, 1642-3. The ſtory is variouſly told by the different parties; but it ſtands on record as an inſtance of the fatal effects of civil diſcord, from the outrages of which no place, however ſacred, is exempt.

Of the archbiſhop's palace, the chief object of note in the pariſh, it will be proper to ſtate a few particulars. It is ſituated near the river; and is certainly a very large pile of building, exhibiting the architectural ſtyles of various ages. It appears that this palace was, in a great meaſure, if not wholly, rebuilt by archbiſhop Boniface in the year 1262. If any part of this ſtructure now remains, it is the chapel; the architecture of which might induce one to aſcribe it to a more early period. Under the chapel is a crypt, the arches of which are built with ſtone, as is the chapel; the roof of the latter is of wood and flat; the windows were formerly of painted glaſs, put up by cardinal Morton. In the chapel were interred the remains of archbiſhop Parker. The great

hall was rebuilt by archbishop Juxton, after the civil wars, at an expence of 10,500*l*. It is 93 feet long by 38 wide; and has a fine carved wooden roof. The guard room, built before the year 1428, has a roof similar to that of the hall. Cardinal Pole is said to have erected the long gallery, which measures 90 feet by 16. In this room are several portraits of archbishops, and other illustrious characters. In the great dining-room, 38 feet by 19, are also portraits of all the archbishops from Laud to the present time; this series is particularly interesting, as, among other things, they shew the gradual change of the clerical dress. Archbishop Tillotson was the first to wear a wig; which however resembled the natural hair, and was worn without powder. A noble library occupies four galleries, over a small quadrangular cloister. The first collection of books was bequeathed by archbishop Bancroft; but these were seized in the civil wars, and though much injured, and some lost, yet the chief stock was restored by archbishop Juxton, after the restoration. Archbishops Sheldon, Tenison, and Secker augmented the library; and the number of books is now supposed to be, at least, 25,000 volumes. In the windows is some fine painted glass. (See Brayley and Herbert's Illustrations of Lambeth Palace, 4to. 1806, for various views of this palace, and portraits, &c. from the painted glass). The MS. library contains a large and valuable collection of records and MSS. At the west end of the chapel is a lofty building, called Lollards' tower, built by archbishop Chichele in the years 1434 and 1435. At the top is a small room called the prison, in which it is said the Lollards were confined. The gateway, and the adjoining tower, which are of brick, were built by archbishop Morton about the year 1490. The gardens and park, which contain nearly thirteen acres, are laid out with great taste; they were much improved by the late archbishop, who made a convenient access to the house, for carriages, through the park. It has been said, but erroneously, that Stephen Langton is the first archbishop upon record who resided at Lambeth. Hubert Walter was there in 1198; and many of the public acts of the metropolitan were performed at Lambeth prior to that period.

Contiguous to the palace is the parish church, which was rebuilt between the years 1374 and 1377. The tower, which is of free-stone, still remains; the other parts of the present structure appear to be about the age of Henry VII. The church now consists of a nave, two aisles, and a chancel. Two chapels, called Howard's and Leigh's, were built in 1522; they were incorporated with the church when it was repaired in 1769. Among the numerous sepulchral memorials in this church, those most worthy notice are for the archbishops Tenison, Hutton, and Cornwallis, and a marble slab to the memory of the celebrated antiquary Elias Ashmole.

In this parish are situated the Asylum, instituted in 1758, for the reception of female orphans; and the Westminster Lying-in-Hospital, built in 1765.

About the end of the seventeenth century, a manufacture of plate glass was established at Vauxhall, in this parish, under the patronage of the duke of Buckingham; the principal artist was Rossetti. It was carried on with great success, and the glass was thought to excel that made at Venice. (See GLASS and LOOKING-GLASS.) The importation of foreign timber, which for many years has formed a considerable and important branch of our commerce, has been a source of wealth to this parish, where are several wharfs for that trade, supplied with stores which are almost incredible. At Vauxhall are some very large distilleries, and several potteries; the manufacture of stone earthenware pots is said to have been first introduced here from Holland. On the scite of Cuper's gardens (formerly a place of public entertainment,) are Messrs. Beaufoy's extensive vinegar works. Mr. Pennant, who went over the premises, mentions a vessel full of sweet wine, containing 58,109 gallons, and another full of vinegar, containing 56,799 gallons; besides these enormous vessels there are several others which contain from 32,500 to 16,974 gallons each. In the year 1769, Mrs. Coade established in this parish, near Westminster bridge, a manufacture of artificial stone, which is cast in moulds and burnt. It is intended to answer the purpose of stone, for every species of ornamental architecture, at a much cheaper rate than carving. Where it has been placed in exposed situations it has been found to endure the frost. Messrs. Watts have lately established a manufacture of patent shot in this parish: the principle of making this shot is, to let it fall from a great height into the water, that it may cool and harden in its passage through the air, and thereby better retain its spherical shape. The height of the tower at this manufactory is about 140 feet; the shot falls 123 feet six inches. About the same time Messrs. Bolton, Morgan, and Co. established a manufacture here under the title of the woollen yarn company; every branch of the clothing manufacture, from sorting the wool to making the cloth, was carried on entirely by machinery; but the undertaking was soon given up. About a century ago, there was a place of entertainment called Lambeth Wells, situated in what is now called Lambeth Walk. A riding-school, for the exhibition of feats of horsemanship, was opened in this parish about the year 1768, by Mr. Philip Astley. At first it was an open area; in 1780 it was converted into a covered amphitheatre, and divided into boxes, pit, and gallery. Spring Gardens, Vauxhall, (which is mentioned in the Spectator as a place of great resort,) is open during the greater part of the summer, being illuminated with a great number of lamps; the entertainment consists of a concert of music, performed, in fine weather, in the open air; the price of admission, till 1796, was one shilling; it is now three shillings, and open three times each week during the summer months. Lysons's Environs of London, vol. i. 4to.

Lamp

LAMP, an inftrument ufed for the combuftion of liquid inflammable bodies, for the purpofe of producing artificial light.

The moft fimple lamp confifts of a veffel of almoft any fhape, containing oil or alcohol, with a tube projecting a little above the furface of the liquid, and containing any fibrous fubftance capable of raifing the liquid to the top of the tube, by capillary attraction. The oil, thus raifed and diffufed through the fibrous fubftance, is fo detached from the main body of the liquid, as to admit of being heated to a temperature fufficient to volatilize the oil, the vapour of which, in a ftate of combuftion, conftitutes the flame of the lamp.

In the management of the lamp of the moft fimple kind, fo far as relates to the fupply of oil, three things are neceffary to be obferved. 1. The wick muft be of fuch a fubftance as beft to promote capillary attraction. 2. It fhould not be twifted too much, in which cafe its capacity for the oil is too little; nor fhould it be fo loofe as to diminifh materially its capillary attractive power. This is frequently the cafe, when the wick has been too long immerfed in the oil. 3. With regard to the diftance of the flame from the furface of the oil.—If the flame be too near the furface, a leffer quantity of oil will acquire the intenfe heat neceffary to raife it into vapour, fince the heat communicates with the fluid. On the contrary, when the flame is too high above the oil, the capillary attraction, which decreafes in fome ratio of the diftance, is infufficient to fupply the neceffary quantity of oil.

Experience has long ago eftablifhed, that cotton is the beft medium for the tranfmiffion of the oil, which is prepared in a particular way for the purpofe.

During the flow combuftion of oil, as obferved in the common lamp, as well as that of tallow in candles, the fatty matter is decompofed, producing a quantity of vapour, which inflames in contact with oxygen; and a cloudy exhalation in the form of fmoke, confifting of numerous fmall particles of carbonaceous matter, which, if collected, conftitute the article called lamp-black. Befides the offenfive fmell and appearance of this fubftance, there is an evident wafte of combuftible matter, capable of producing both light and heat.

The evil arifing from the fmoke and fmell of lamps was formerly fo great, as to prevent their introduction into domeftic ufe, notwithftanding the ftrong inducement of convenience and economy.

The public have long been in poffeffion of a complete remedy for this, and feveral other difadvantages in lamps, by the invention of the Argand lamp. This invention embraces fo many improvements upon the common lamp, and has become fo general throughout Europe, that it may be juftly ranked among the greateft difcoveries of the age. As a fubftitute for the candle, it has the advantage of great economy and convenience, with much greater brilliance; and for the purpofe of producing heat, it is an important inftrument in the hands of the chemift.

We may with fome propriety compare the common lamp and the candle to fire made in the open air, without any forced method of fupplying it with oxygen; while the Argand lamp may be compared to a fire in a furnace, in which a rapid fupply of oxygen is furnifhed by the velocity of the afcending current. This, however, is not the only advantage of this valuable invention. It is obvious that if the combuftible vapour occupies a confiderable area, the oxy-

gen of the atmofphere cannot combine with the vapour in the middle part of the afcending column. The outfide, therefore, is the only part which enters into combuftion; the middle conftituting fmoke. This evil is obviated in the Argand lamp, by directing a current of atmofpheric air through the flame, which, inftead of being raifed from a folid wick, is produced from a circular one, which furrounds the tube through which the air afcends. Before we enter more fully into the merits of the Argand lamp, we fhall give a defcription of it, with reference to drawings of its different parts. Thefe drawings are taken from the lamps of modern conftruction, which have recently been much improved. The wick is now raifed by a fcrew, inftead of the rack and pinion; which is fo great an improvement upon the latter, both in fimplicity and convenience, that it is becoming general.

Fig. 1. (*Plate Lamps*) is a view of the lamp complete, to a fcale of one-third the real fize. A is a refervoir, which is on the principle of the bird-fountain, keeping the oil always at the fame height in the burner B, through the communication C.

The burner B is compofed of three tubes, *a*, *b*, and *c*. The two firft are feen in fection only; while the whole of one fide of *c* is feen.

Fig. 2. The tube *c* is foldered into the bottom of the tube *a*, and open throughout, communicating with the receptacle D, which fcrews on the outfide of the tube *a*, and ferves at once to catch the oil which may accidentally run over the tube *a*, and admit the air through the apertures *n*, *p*, which has to afcend through the tube *c*.

The oil which comes in through C will occupy the cavity *g b*, between the exterior furface of the tube *c*, and the interior of *a*, which muft, of courfe, rife to the height of the aperture *t*, in the refervoir A, as feen in *fig*. 3. The part *de*, *fig*. 2, called the bucket, is a fhort tube to receive the circular wick. This part is feen in *fig*. 4, with the wick upon it, *d f*. It is made to work freely upon the tube *c*. The latter has a fpiral groove cut upon it, into which a pin at *o* enters; fo that when the bucket is turned round by a catch *r*, which works in a longitudinal flit in *b*, it will be raifed or lowered by turning the tube *b* in different directions, and is, therefore, the means of raifing or lowering the wick.

A wire, *s*, is attached to the tube *b*, which bends down parallel to, and touching the outfide of, the tube *a*. The part *k l x z y* fits upon the tube *a*. The part *k l* is provided with fhallow fides to receive the glafs E, and is connected with a ring *y*, by wires *x*, *z*, *fig*. 1. The whole of this part turns with the glafs E, and at the fame time carries round the tube *b*, by means of the wire *s*, which is connected to *k l* and *y*, for the purpofe of raifing or lowering the wick. When oil is to be introduced into the refervoir, A is fcrewed off, and inverted. The aperture *t*, *fig*. 3, is then opened, by pufhing down the fliding focket *v*, which ought to fit the interior cylinder pretty accurately. The globe muft now be filled at the hole *t*: the focket *v* is next pulled over the hole. The ball may now be held in an erect pofition, and replaced in the lamp; after which the focket *v* may be pufhed below the hole *t*, by means of the handle *w*. The oil will now rife to a height in F, and in B, till it reaches the higher part of the aperture *t*, *fig*. 3, and will maintain the fame height till the oil in the globe gets to the fame level. The reafon of this hydroftatical phenomenon will be eafily perceived. When the oil in B and F gets a little below the aperture *t*, a bubble of air enters and afcends into the globe, the fame quantity of oil defcending to give it place.

This refervoir, although it is fully fitted for giving a regular fupply of oil, is attended with one difagreeable property. The air in the upper part of the globe being much more expanfible by heat than liquid bodies in a warm room, its fpring becomes greater than the preffure of the exterior air; in confequence of which, the oil is apt to flow over the tube *a*, and liable fometimes to overflow the veffel D. Another difadvantage is alfo attendant on this bulky refervoir. When the lamp is ufed on a table, the fhadow renders one fide of it ufelefs. The above inconveniences in the Argand-lamp have been, in fome meafure, obviated by the invention of Mr. Peter Kier of Kentifh Town. He raifed the oil by means of a column of a heavier fluid. In the plate, *figs*. 5 and 6, are exhibited an elevation and fection of one of thefe lamps; the fection only requires to be explained. From the flender figure of the vafe, it is evident that the flame is permitted to throw its light in all directions, downwards and upwards, nearly in the fame manner as a candle. The interior part is divided into feveral compartments by the diaphragms at F and C. The fpace A A above F is open to the atmofphere; but the fpace B B, beneath C, is clofe. A tube F G proceeds from the fpace A A to the fpace B B, fo as to reach nearly to the bottom at G, and another tube, C D, proceeds from B B upwards through A A, without communicating with this laft fpace, and is enlarged at the upper part, fo as to receive a wick with the apparatus of Argand, or any other. A folution of fea-falt, or the mother water of falt, being firft poured in, by meafure, at E, flows down the tube into B B, and fills that fpace. A like meafure of oil is next poured, which alfo defcends into B B, and forces the denfe faline liquor upwards through G F into the fpace A A. The fpecific gravity of this laft is adjufted by dilution; fo that when the fpace A A is properly filled, the oil fhall ftand in equilibrio at the requifite height near E, *viz*. the furfaces in A and at E are elevated above the lower orifice at G, in the inverfe proportion of the fpecific gravities.

This proportion is ufually about three to four; fo that if any of the oil be taken away from E by combuftion, or otherwife, there will be a fubfidence of the heavy fluid in A A to preferve the equilibrium; and during the whole fubfidence in A A, there will be a correfpondent depreffion of the upper furface of oil, near E, which will be meafured by four-third parts of the firft elevation of the denfe fluid above the partition F D. Now, the fall in A A may be rendered very fmall, by enlarging the diameter of the veffel at that part, and at B B; and the elevation of E above A, and, confequently, the infulation of the radiant flame, may be governed at pleafure by prolonging the interval D C.

It is poffible, in the manipulation of this lamp, that fome oil, or pieces of fnuff, may fall into the fpace A A, and float upon the liquid. This effect is, to a certain extent, beneficial, becaufe the covering of oil prevents evaporation; but if this fhould require to be remedied, it is eafily done, by pouring the whole contents of the lamp into a bafin, and after a few moments repofe, or ftraining, returning the liquids again into the lamp at E by a fyphon, or funnel, in which they will take their proper places by means of their relative weights. We may recapitulate the good qualities of this lamp in a few words. 1. It is capable of any form or apparatus for the burners. 2. It prefents no obftacle to intercept the emitted light. And, 3. As it raifes the oil by the mere gravitation of a non-elaftic fluid, it cannot, in any cafe, like the fountain lamp, raife more than is wanted.

A great variety of other lamps are at prefent expofed for fale, having different means of fupplying the oil, but none fo fufficiently ftriking as to merit minute defcription.

The grand and most essential properties of the lamp are confined to the means of supplying the flame with oxygen, so as to produce the most perfect combustion, and for which we are almost entirely indebted to *Argand*. We shall therefore conclude this article with some remarks upon the merits of this valuable invention, and shew in what instances it has been improved in its most essential points.

In the original lamp of Argand, a perpendicular column of air was perpetually ascending through the glass chimney of the lamp; one part of it passing through the central tube *c*, *figs.* 1 and 2; and the rest through the holes *q* and *m*, round the circular plate *k l*. This part was formerly a cylinder extending down to the receptacle D.

With this perpendicular current alone, it is well known that the Argand lamp would not burn *whale oil*, and the purification of this oil, to render it fit for the purpose, became a desideratum, on account of the high price of the spermaceti oil. This great object was not accomplished by purifying the oil, but an improvement was made in the lamp itself, which effectually answered the desired purpose. For this discovery we are indebted to an ingenious and scientific manufacturer of Derby. It is curious to observe, however, that no advantage was taken of this invention for twenty years, during which time it had been used in the cotton mills of this discoverer, and now the same end is accomplished by a simpler contrivance. The above improvement consisted in placing over the mouth of the tube *c* a plate of metal about the diameter of the tube, and at such a height as to be a little short of the apex of the flame. By this means the ascending column of air was turned out of its perpendicular course, and thrown immediately into that part of the flame where the smoke was formed, and which, by this means, was completely consumed, producing at the same time a more than ordinary brilliant light.

The same effect is now produced by the shape of the lamp glass E, in the figures already alluded to. The exterior current of air which enters the holes *q*, *m*, &c. rises with a velocity proportioned to the length of the glass chimney, and to the rarefaction of air in the same, strikes upon the shoulders N and O, by which it is propelled into the upper part of the flame. This happy form in the glass appears to have been the result of accident. Had the manufacturer been aware of its importance, it would have either been the subject of a patent, or at least strongly recommended to the public in the way of puffing. We see at the present time different shaped glasses, some of which are rather worse than the original plan, instead of improvements.

The theory of the action of the chimney lamp, is so nearly allied to the principles of furnaces, which we have given under that article, that the reader will no doubt get some useful hints, relative to the construction of lamps, by perusing the same.

The hydro-pneumatic lamp is constructed upon similar principles to the celebrated water engine erected by father Hell, at Chremnitz, in Hungary; the descent of one-half of the fluid to a certain depth below the source, raises the other half an equal height above the source. This principle has been, with great success, applied to the lamp, we believe at first by the French, but has lately been brought to perfection by Mr. R. W. King, of Holborn, who manufactures these articles. *Figs.* 1, 2, and 3, of *Plate* II. explain the construction of this ingenious contrivance. *Figs.* 1 and 3 are sections to which our description will principally apply; A A is a cylindrical vessel, divided by horizontal partitions into four chambers, *viz.* B, C, D, and E. The upper one, B, is to contain the oil which is for the immediate supply of the flame: the next, C, is for the portion of oil which descends into the inferior chamber E, through the pipe *a*, and forces the contained air up through the pipe *b*, into the upper chamber B, and pressing upon the surface of the oil contained therein, causes it to ascend the pipe *d*, to the lamp F, which is on Argand's principle, and of the same construction as before explained: *e* is a pipe to conduct the external air down into the chamber C; and *f* is a pipe to convey the waste oil, which may drip down from the lamp, into the middle chamber D, which is merely a reservoir for such waste oil. G is a tube passing down to the second chamber C, to fill it with oil; it is closed at pleasure by an air-tight plug *b*, fitting into the end of it; the lower orifice of the pipe *a* is closed by a piece of hat *i*, acting as a valve, which is shut by a spiral spring beneath it, but opened by a wire passing down the tube *a*, and also through the filling tube G, the plug of which, when in its place, presses down the wire, and opens the valve: suppose the plug removed, the spring will close the valve *i*. Oil is now poured in at the end of the pipe G; it runs down into the chamber C, and fills it, then rises in the pipe, which having a hole in one side, near its upper end, the oil also flows into, and fills, the upper chamber B. The plug *b* is now inserted into its place; this shuts off the communication of the open air, both with the chambers B and C, but depressing the wire, as before explained, opens the valve *i*, and the oil in the middle chamber C descends, by its gravity, through *a*, as shewn by the arrow, and enters the lower chamber E, from which it expels the air by the pipe *b*, into the chamber B. The end of this pipe being covered by an inverted hood, the air ascends by bubbles, through the oil, into the top of the chamber, and pressing on the surface of the oil, forces it up the pipe *d*, to the lamp in which it stands at the level of the dotted line *k*, at which level it will evidently continue, till the upper chamber is exhausted, and the contents of C descended into E. The lamp is now replenished by the following means; the whole apparatus is inverted, as shewn in *fig.* 3; the oil now runs down the pipe *b*, and filling its hood, flows over into the upper chamber B, which it fills, the atmospheric air entering the pipe *e* into the chamber C, and thence by the pipe *a* into the chamber E, the air contained in the chamber B escaping at the pipe *d*. The lamp is held inverted for about a minute, and is then set upright. Fresh oil is now poured in at the plug *b*, to fill the second chamber C, and then the plug being put in, the above operation is repeated.

By this ingenious application of the principles of hydrostatics, the lamp F is constantly supplied with oil at precisely the same level, which does not vary by any diminution of the quantity of oil, or by the expansion of the air by heat, as in the fountain lamp, the included air being only applied as the medium to transmit the pressure of one column of oil, from C to E to act upon, and raise a similar column from B to the dotted line *k*. The lamp is furnished with a glass chimney H, similar to that before described, and for some purposes this is surrounded by a glass globe K, ground withinside to take off the glare of the light. The cylindric vessel A A is included in an elegant columnar pedestal, shewn in *fig.* 2, where the ring L is that which is turned round to elevate the wick. *Fig.* 4. is a cap to cover the top, when the glass chimney is removed. The principal objection to this lamp, as originally constructed, was, that after inverting it, the oil would, in certain positions of the lamp, return down the pipe, and fill the lower chamber again, in which state it would not burn. Mr. King has completely remedied this, by bringing all the tubes, except the air and filling tubes, as near as possible into the centre of the lamp. Lamps of this

kind have been made to contain a ſufficiency of oil to laſt two months, the veſſel having the appearance of an elegant pedeſtal to ornament a hall or ſtaircaſe.

A patent lamp, invented by John Barton, eſq. is delineated in *fig*. 5. of our plate; it is contrived ſo as to always have a ſupply of oil maintained at a level, very near the point of combuſtion, by floating the oil upon a fluid of greater ſpecific gravity. The oil is contained in a cylindrical veſſel A, *fig*. 5, having a pipe, B, extending upwards from it to the burners at *a*, *a*, *a*, where the wicks are placed. The bottom of the veſſel takes off with a ſcrew joint, ſimilar to a ſnuff-box, that the inſide of the veſſel may be cleaned; and in the centre of the bottom is an aperture of about half an inch in diameter always open. This oil-veſſel is immerſed in a heavier fluid, contained within the external veſſel D E F G. A float is attached to the oil-veſſel at H, and another, in addition to it, is fixed to the tube B at I. In this ſituation of things, the column of heavy fluid, (which may be ſalt water,) from its ſurface at *c* to *d*, where the oil preſſes upon it, (through the hole in the bottom of the oil-veſſel,) will ſupport a column of oil, of a greater height, in proportion to the difference of their ſpecific gravities, from *d* up to *e* for inſtance, within an inch of the burners *a*, *a*, which is a ſufficiently ſmall diſtance for the capillary attraction to draw up a ſupply of oil to the wick. As the oil diminiſhes by burning, the water enters the hole in the bottom of the oil-veſſel, and ſtill continues to ſupport the column of oil, as at firſt, the oil-veſſel floating in the water by the floats at H and I. By this means it is freed from the inconvenience we have before aſcribed to Mr. Kier's lamp, becauſe the burners deſcend as the oil is conſumed; and therefore, though the oil is not maintained at the ſame identical level, yet, with reſpect to the burners, it is always at the ſame diſtance below their wicks. The external veſſel unſcrews at F, to get in the oil-veſſel A. The enlarged part or vaſe D, at the top, ſhould contain very nearly, but not quite, as much as the oil-veſſel. In preparing the lamp, the external veſſel is firſt filled with the water (poured in at the top of the vaſe D) as high as E: the oil-veſſel is now full of water, and reſts upon the bottom, becauſe the upper float I is not ſupported. The oil, being poured in at the top of the tube B, expels the water from the veſſel, and fills it at the ſame time, raiſing the water in the vaſe D, and floating the oil-veſſel. In this ſtate the lamp will continue, with the oil ſtanding at *e*, until it is all conſumed.

A very ſimple and efficacious lamp has been lately preſented to the public, under the title of the Automaton lamp, having ſomething ingenious in the manner of ſupplying it with oil. We have given three figures of it at *figs*. 6, 7, 8, of the laſt plate; it conſiſts of a tin box, *a b c d*, with a burner conſiſting of two wicks of cotton at *a*. The box is ſuſpended upon pivots at *e*, entering eyes in the wire *f*, which is ſimilar to the ſuſpenſion part of a ſcale-beam. When this lamp is full of oil, which is poured in at *d*, it aſſumes the horizontal poſition *fig*. 6, becauſe the maſs of oil, *a b c d*, is chiefly ſituated behind the centre *e*, and balances the weight of the wick at *d*; but as the oil diminiſhes by burning, the weight behind the centre is leſſened, whilſt that of the wick continues without alteration. This occaſions the lamp to librate, as in *figs*. 7 and 8, ſo that the oil is always kept very near the wick, by which means it will burn oil which is too impure for the capillary action of a common lamp. The nicety of its performance depends upon the figure of the veſſel, and the place of the centre *e* correſponding with the weight of the tubes at *d*. This the makers have by experience determined to the greateſt accuracy.

The Automaton lamp is in very general uſe in the north of England in cotton-mills, and other manufactories where the gas-lights are not introduced, which is undoubtedly the beſt method.

Lamp, *Cardan's*, is a contrivance of an author of that name, which furniſhes itſelf with its own oil.

It conſiſts of a little column of braſs, tin, or the like, well cloſed every where, excepting a ſmall aperture at bottom, in the middle of a little gullet or canal, where the wick is placed.

Here the oil cannot get out, but in proportion as it waſtes, and ſo opens the paſſage of that little aperture.

This kind of lamp was much in uſe ſome years ago; but it has ſeveral inconveniences: ſuch as that the air gets into it by ſtarts and gluts; and that when the air in the cavity comes to be much rarefied by heat, it drives out too much oil, ſo as ſometimes to extinguiſh the lamp.

Dr. Hook, and Mr. Boyle, have invented other lamps that have all the conveniences of Cardan's without the inconveniences.

The flame in a lamp never conſumes the wick, till the wick be expoſed to the air by the flame's falling downward; and from thence it may be inferred, that a way found out to keep the fuel, and conſequently the flame, at the ſame height upon the wick, would make it laſt a long time. Many ways have been deviſed to arrive at this, but it ſeems only poſſible to be done, in any degree of perfection, by hydroſtatics. Thus, let a lamp be made two or three inches deep, with a pipe coming from the bottom almoſt as high as the top of the veſſel; let it be filled ſo high with water, as to cover the hole of the pipe at the bottom, to the end that the oil may not get in at the pipe, and ſo be loſt. Then let the oil be poured in, ſo as to fill the veſſel almoſt brimful, which muſt have a cover, pierced with as many holes as there are wicks deſigned. When the veſſel is thus filled, and the wicks are lighted, if water falls in by drops at the pipes, it will always keep the oil at the ſame height, or very near; the weight of the water being to that of the oil as $20\frac{1}{8}$, to 19, which in two or three inches makes no great difference. If the water runs faſter than the oil waſtes, it will only run over at the top of the pipe, and what does not run over will come under the oil, and keep it at the ſame height. Phil. Tranſ. No. 245, p. 388.

The acceſs of air is of the greateſt importance in every proceſs of combuſtion. When a lamp is fitted up with a very ſlender wick, the flame is ſmall and of a very brilliant white colour: if the wick be larger, the combuſtion is leſs perfect, and the flame is brown: a ſtill larger wick not only exhibits a brown flame, but the lower internal part appears dark, and is occupied by a portion of volatilized matter, which does not become ignited until it has aſcended towards the point. When the wick is either very large or very long, part of this matter eſcapes combuſtion, and ſhews itſelf in the form of coal or ſmoke. The different intenſity of the ignition of flame, according to a greater or leſs ſupply of air, is remarkably ſeen by placing a lamp with a ſmall wick beneath a ſhade of glaſs, not perfectly cloſed below, and more or leſs covered above. While the current of air through the glaſs ſhade is perfectly free, the flame is white; but in proportion as the aperture above is diminiſhed, the flames become brown, long, wavering, and ſmoky; it inſtantly recovers its original whiteneſs when the opening is again enlarged. The inconvenience of a thick wick has been long ſince obſerved, and attempts have been made to remove it; in ſome inſtances by ſubſtituting a number of ſmall wicks inſtead of a larger; and in others, by

making the wick flat instead of cylindrical. The most scientific improvement of this kind is the lamp of Argand, described in the preceding part of this article. In this the wick forms a hollow cylinder or tube, which slides over another tube of metal, so as to afford an adjustment with regard to its length: when this wick is lighted, the flame itself has the figure of a thin tube, to the inner as well as the outer surface of which the air has access from below. And a cylindrical shade of glass serves to keep the flame steady, and in a certain degree to accelerate the current of air. The inconvenience of a long wick, which supplies more oil than the volume of flame is capable of burning, and which consequently emits smoke, is seen at once by raising the wick; and on the other hand, the effect of a short wick, which affords a diminutive flame merely for want of a sufficient supply of combustible matter, is observable by the contrary process. The most obvious inconvenience of lamps in general, arises from the fluidity of the combustible material, which requires a vessel adapted to contain it, and even in the best constructed lamps is more or less liable to be spilled. When the wick of a lamp is once adjusted as to its length, the flame continues nearly in the same state for a very considerable time. Nicholson's Journal, vol. i. 4to.

By 17 Geo. II. cap. 29. a convenient number of glass lamps shall be put in such places of the city of London, as the mayor, aldermen, and commonalty shall think fit; to be kept lighted and burning from sun-set to sun-rising throughout the year; and rates shall be made not exceeding *6d.* in the pound, nor above 50*s.* a year on any one person, for defraying the charges of them. Every alderman, with consent of his deputy and common council, may contract yearly for the setting up lamps, and their lighting, trimming, &c. and persons maliciously breaking down or extinguishing the lamp, shall forfeit 40*s.* for the first offence; 50*s.* for the second; and 3*l.* for the third, leviable by justices, or to be sent to the house of correction. By stat. 11. Geo. III. c. 29. for paving and lighting London, the wilfully breaking or extinguishing of any lamp incurs the penalty of 20*s.* for each lamp or light destroyed or extinguished. None but British oil is to be used for lamps in private houses, under penalty of 40*s.* 8 Ann. cap. 9.

The use of lighted lamps in churches, and places of devotion, is very ancient. In the city of Fez is a mosque, wherein are 900 brazen lamps burning every night. In Turkey, all the illuminations are made only with lamps. Polydore Virgil ascribes the first invention of lamps to the Egyptians; and Herodotus describes a feast of lamps held annually in Egypt.

Kircher shews the manner of preparing lamps, which shall diffuse a light so disposed, as to make the faces of those present appear black, blue, red, or of any other colour.

There has been a great dispute among the learned about the sepulchral lamps of the ancients: some maintain, they had the secret of making lamps that were inextinguishable, alleging several that have been found burning, at the opening of tombs fifteen or sixteen hundred years old. But others treat these relations as fables; and others think, that the lamps, which were before extinguished, took light afresh upon the admission of fresh air.

Dr. Plott, however, is of opinion, such perpetual lamps are things practicable, and has himself made some proposals of this kind. The linum asbestinum, he thinks, may do pretty well for the wick, and that the naphtha, or liquid bitumen, constantly springing into some of the coal-mines, would answer for the oil.

If the asbestos will not make a perpetual wick, he thinks there is no matter in the world that will; and argues, that the tradition of such lamps must be fabulous, or else that they made them without wicks.

Such a lamp he thinks it possible to make of the bitumen springing into the coal-mines at Pitchford, in Shropshire; which, he says, like other liquid bitumen, will burn without a wick.

Those lamps that kindle on the immission of fresh air, the same author thinks, might be imitated by inclosing some of the liquid phosphorus in the recipient of an air-pump; which, under those circumstances, will not shine at all; but on letting the air into the recipient, there will possibly, says he, appear as good a perpetual lamp as some that have been found in the sepulchres of the ancients.

Lamp, *Rolling*, in *Mechanics*, is a lamp A B (*Plate* I. *Lamps, fig.* 7.) that has within it the two moveable circles D E and F G, whose common centre of motion is at K, where their axes of motion cross one another, in which point also is their common centre of gravity. If to the inward circle you join withinside the lamp K C, made pretty heavy, and moveable about its axis H I, whose centre of gravity is at C, the common centre of gravity of the whole machine will fall between K and C, and by reason of the pivots A, B, D, E, H, I, will be always at liberty to descend; and, therefore, let the whole lamp be rolled along the ground, or moved in any manner, the flame will always be uppermost, and the oil cannot be spilt. In this manner the compass is hung at sea; and thus should all the moon-lanthorns be made that are carried upon a pole before coaches or carriages which travel in the night. Desag. Exp. Phil. vol. i. p. 57.

Lamp-*black*. Of this kind there are two sorts; one of which is the light soot, obtained from burning pine and other resinous wood; and another, which is the heavy black, obtained by calcining bones in close vessels. See Black. See also Bone and Charcoal.

Lamp-*blowers* are persons who form various articles of glass for toys, and for more important philosophical purposes, from tubes, &c. by means of the *blow-pipe*; which see.

The apparatus of these artists consists of a solid table, to the bottom of which is fixed a double bellows with a foot-board, from which proceeds a pipe that conducts the blast to the lamp. This lamp is a large bundle of cotton threads, placed in a tin vessel in the shape of a horse-shoe, and supplied by lumps of tallow deposited by it, and pushed into the flame as the continued combustion requires. The smoke is conveyed away by a small chimney suspended over the lamp. The blast-pipe in front of the table, at which the artist is seated, drives the jet of flame away from him, so that he suffers no inconvenience from it.

The other articles of his apparatus are glass tubes of various dimensions, and two or three very simple iron tools, such as a small forceps, files, &c. The flame in full vigour is about four inches in length, which near its extremity is of a clear light blue, when it is the hottest, and beyond of a pale yellow. The tubes, before the operation commences, are well dried, so as to be quite free from moisture. They are then gradually heated by being first held in the flame of the lamp without blowing, and then at the edge of the outer yellow part of the jet of flame, and slowly brought to a state of fusion. The flame is sufficiently strong to bring to a very white-red heat a solid mass of glass, about the size of a playing marble, or even larger; and this, when blown out very thin, will make a bulb of the capacity of three ounces, which is nearly the extent of the power of the common lamp-blowing. The bulbs for thermometers and other phi-

losophical purposes are much less. (Aikin's Dict. vol. i. art. *Glass*.) For an account of the operation of hermetical sealing, performed by the lamp-blowers, see HERMETICAL *Sealing*. For bending and joining glass-tubes, forming bulbs to tubes, and spinning out glass-threads, see TUBE, THERMOMETER, and THREADS.

LAMP *furnace*, is a furnace, in which the heat is produced and maintained by the flame of a lamp introduced within it. This furnace has no occasion for an ash-hole, a grate, or a fire-place. It has only one opening below, through which the lamp is introduced, and a kind of small chimney in its upper and lateral part, for circulation of air, to keep up the flame of the lamp, and to give vent to the smoke. For the description of an improved furnace of this kind, see Lewis's Com. Phil. Techn. p. 29. See FURNACE.

Argands.

Fig 1

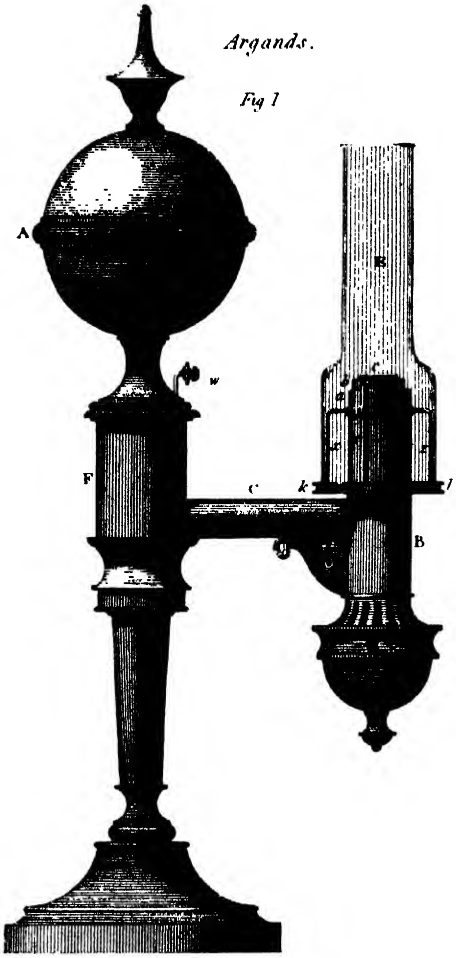


Fig 6.

Mr. Kier's.

Fig 5.

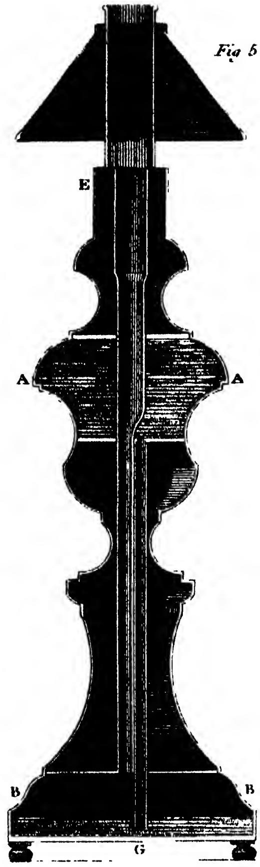


Fig. 3.

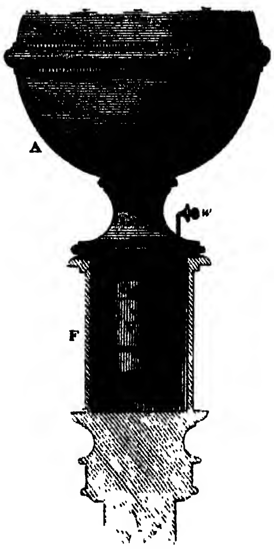


Fig 2.

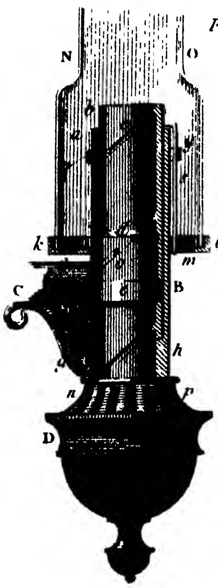
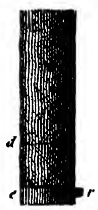


Fig 4
Lamp Cotton.



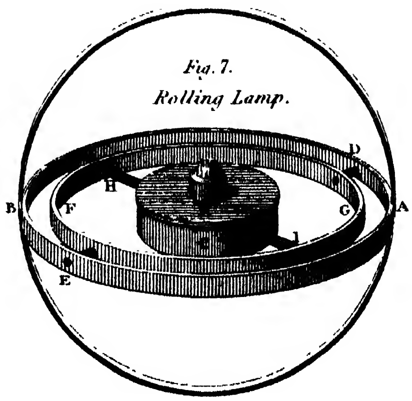


Fig. 7.
Rolling Lamp.

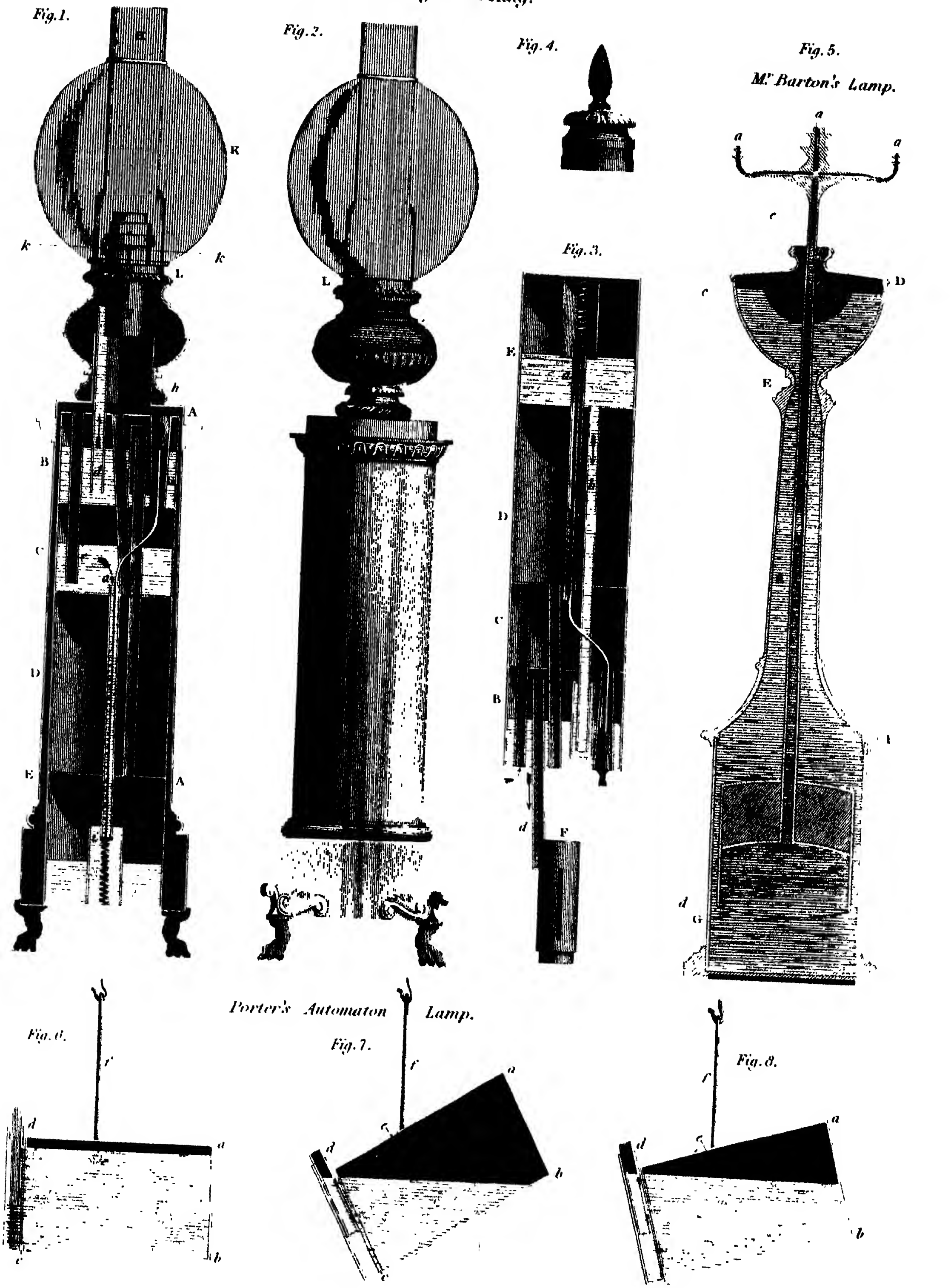
Published as the Act directs 1814 by Longman, Hurst, Rees, Orme & Brown, Paternoster Row, London

Lowry sculp.

LAMPS.

PLATE 1

Hydro-Pneumatic Lamp by R. W. King.



J. Farey del.

Published as the Act directs, 1817, by Longman, Hurst, Rees, Orme, & Brown, Paternoster Row.

Lanarkshire

LANARKSHIRE, an inland county in the ſouth of Scotland, is frequently denominated *Clydeſdale*, from the river Clyde, which flows through it longitudinally in a winding courſe of more than ſixty miles. The ſituation of this county is between 55° 22′ and 55° 58′ north latitude, and between 3° 15′ and 4° 19′ weſt longitude. It is bounded by Dumfries-ſhire on the ſouth, by the ſhires of Ayr and Renfrew on the weſt, by the counties of Dunbarton and Stirling on the north, and by thoſe of Linlithgow, Edinburgh, and Peebles on the eaſt. Its length from north to ſouth is about forty-ſeven miles, and its breadth nearly thirty-two. The pariſhes it contains are forty-eight in number, inhabited, according to the parliamentary returns in 1800, by a population of 150,690 perſons. The ſurface contents are 927 ſquare miles, or 593,280 ſtatute acres. Lanarkſhire anciently formed a great portion of one of the principalities into which Scotland was divided at the time of the Roman invaſion. The name given to this kingdom was Strathclyde, which comprehended, beſides the county of Lanark, thoſe

of Stirling, Dumbarton, and Renfrew. This shire is divided into three districts, or wards, formerly known by the appellations of Clydesdale, Douglasdale, and Avondale, but these are now more frequently termed the upper, middle, and lower wards. Each of these districts is subject to the particular jurisdiction of a substitute appointed by the sheriff-depute of the county.

With respect to the *soil* and *appearance* of this county, the upper parts of it, except in the vicinity of the Clyde, are so hilly and moorish, as scarcely to be susceptible of any improvement from agriculture. The elevation of the hills is in general very great; some of them rise to the height of 600 feet above the level of the sea. Notwithstanding this, they exhibit but little grandeur, the perception of their size and altitude being much modified by the closeness with which they are crowded together. The chief part of the arable lands in the upper district, lies in the parishes adjoining to the hill of Tintoe, round which the Clyde flows with a slow and gentle current, washing, in its course to Lanark, twelve miles of the finest meadow-fields in Scotland. In the neighbourhood of Biggar, one of the towns in this district, the soil is uncommonly rich and fertile. This fertility is in many places principally owing to the inundations of the Clyde, which are likewise often the source of irreparable damage, by carrying off, not only the crops, but even the very soil it had formerly enriched. Proceeding down the river, the soil is found to be dry, light, and friable, but less productive than in the vicinity of Tintoe. Carlicke parish is of a clayey soil, but excellent in quality. This parish, and indeed all the parishes situated along the river, are particularly distinguished for the richness and variety of their scenery. Within this district are the falls of the Clyde, celebrated both by the poet and the painter. Above, as well as below these falls, the banks of the river are adorned with numerous country seats, and villages filled with industrious inhabitants.

The middle ward, or district of this county, is not nearly so elevated as that above mentioned. When viewed from any considerable height, indeed, it has the appearance of a level country, though in fact it is much diversified with hill and dale, the former being much less abundant than the latter. The soil of this ward is in general of a clayey texture, and within six miles of the river extremely fertile. The scenery here is no less beautiful than that of the upper ward, the banks of the Clyde being covered with hamlets, orchards, and plantations of various kinds: beyond the range of six miles, however, the country is of a very different description. It is supposed that there are not less than 40,000 acres of moss-land within this district, and such spots as are free from that covering, display a soft clayey soil, formed from a sort of hard clay, lamellated in a horizontal direction, which is called by the farmers *till*, and is known to mineralogists by the name of schistus.

The lower ward is extremely limited in extent, but may rank as the most important of the three, on account of its containing the city of Glasgow, which is justly denominated the Manchester of Scotland, and is perhaps scarcely inferior to Liverpool in point of commercial importance. The lands in this district are naturally barren and unproductive, but in the neighbourhood of Glasgow, the overflowings of a very prosperous commerce have added greatly both to its scenery and fertility. See GLASGOW.

The chief towns in Lanarkshire are Glasgow, Lanark, Rutherglen, Hamilton, Douglas, Biggar, and Carnwarth. Of these the three first are royal boroughs, and will be found described under their respective names. Many considerable villages are likewise scattered throughout the county. The most worthy of notice among these are those of Leadhills and Wilson-town, which are indebted for their prosperity to the mineral productions of the county. *New Lanark*, which owes its origin to the cotton works established there by David Dale, esq of Glasgow, is also a thriving and populous place. These works were first erected in the year 1785, and are perhaps the most extensive of their kind in Scotland. They afford employment to upwards of 1500 persons, many of whom are children. Great attention is paid to their morals and education. The situation of the mills is extremely singular and romantic, being nearly surrounded by high grounds of very steep ascent. They were built on this spot chiefly on account of the great command of water that could be obtained. For this purpose a subterraneous aqueduct has been cut through the solid rocks, for the space of several hundred yards. Both the works and the scenery around are objects of peculiar interest and curiosity. One of the mills contains no less than 6080 spindles.

Besides the Clyde, already so often mentioned, there is a number of other streams in this county, all of which, however, discharge themselves into that river. The chief of those on the northern side are, the Elwin, Glengonan, the Little-Clyde, the waters of Duneaten and Coutten, and the two Calders. None of them are remarkable, except that the two latter are well shaded with wood, and adorned with a number of neat villas. The streams on the southern side of the river are rather more deserving of attention. The Mouse-water is particularly remarkable for that part of its banks called Cartlane-Craigs. These form a curious and romantic den, or dell, somewhat more than a quarter of a mile in length. The rocks on either side rise to the height of four hundred feet, exhibiting a terrific and rugged appearance in one spot, while, in another, the eye is relieved by a pendent covering of coppice wood. At the bottom runs the river Mouse, so closely confined as scarcely to allow room for the lonely traveller to traverse the den. At all the windings of this river the scenery varies, and whenever a rock is found to project on one bank, a corresponding recess may be seen on the other. One of these caverns is still called "Wallace's Cave," from a tradition of its having been for some time the place of that hero's concealment. Logan-water, which rises in the mountain separating the parish of Lesmahago, from that of Muirkirk in Ayrshire, is a beautiful pastoral river. The Avon, which likewise takes its rise on the confines of Ayrshire, after being joined by several minor streams, empties itself into the Clyde near the town of Hamilton. In its course it passes through the inclosures of the duke of Hamilton, where its bold and lofty banks, covered with a variety of shrubs and trees, afford many extremely fine and picturesque views.

No county in Great Britain is more interesting to the geologist, or abounds with a greater variety of *mineral productions*, than Lanarkshire The surface of the upper division of the county generally rests upon whinstone, standing in perpendicular columns. The middle and lower districts, for the most part, exhibit some kind of freestone for their base, but are intersected, at different points, by ridges of whinstone running off from the rocky mountains, downwards, throughout the whole extent of the county. Under the strata of freestone immense strata, or beds of *coal*, are discovered, extending over all the plain country, and branching out, more or less, along the course of the principal waters. The seams of this useful mineral are not entirely of one kind. Where the whole strata remain untouched, a variety of thin and less valuable seams, or strata, present themselves in digging down to what is commonly called the *upper coal*, because it is the first that is found to be worth mining for to any extent. This stratum is composed of the *rough coal*,

except a ſmall portion in the middle of it, which is of the kind called ſplint. After this, comes the *ell coal*, which is much eſteemed for the blackſmith's forge. At from ten to ſeventeen feet beneath this ſtratum, the ſeam called the *main coal* is found. It is ſo named becauſe it poſſeſſes all the good qualities of the other ſtrata, and is preferred, by conſumers in general, to every other ſpecies of this mineral. Below the main coal are four more ſeams. The higheſt of theſe is compoſed of the *humph coal*, the ſecond of the *hard coal*, the third of the *ſoft coal*, and the fourth and laſt ſeam of the *lean* or *ſour-milk coal*. Beneath all are found ſeveral ſtrata of excellent limeſtone, probably as extenſive and inexhauſtible as the valuable mineral which covers it. Independently of theſe ſtrata of coal in the plain, there are others in the higher grounds, but of a diſſimilar nature and arrangement. The hills in the pariſh of Shotts, like the tracts of the ſame elevation in the upper ward, are found to conſiſt of an enormous bed of whinſtone, but in deſcending along their ſides, the freeſtone rock ſhows itſelf lying in a horizontal poſition beneath the whinſtone. Below the free-coal, ironſtone and limeſtone are diſcovered in ſuch vaſt profuſion, as ſeemingly to defy the utmoſt efforts of human induſtry to exhauſt them. Near the Douglas river alſo, extenſive collieries, ſimilar in quality to thoſe of Shotts, are wrought, which ſupply the higher diſtricts of this county and Tweedale, where no coal has yet been diſcovered. To the vaſt ſupplies of this valuable mineral, and its conſequent cheapneſs, the manufacturing proſperity of the weſt of Scotland is to be principally attributed, as, without abundance of fuel, ſcarcely any manufacture can be carried on.

Lead and Iron.—Another great ſource of induſtry and opulence beſtowed on this county by nature, is derived from its mines of lead and iron. The former of theſe metals is chiefly wrought at Lead-hills, a range of mountains in the uppermoſt part of the county, immediately adjoining to Nithſdale. Theſe mines belong to the earl of Hopetoun, and are carried on by two ſeparate companies. The number of miners employed in them is very great. They work only ſix hours out of the twenty-four, ſo that they have much leiſure time, a great portion of which is dedicated to reading. To facilitate this worthy employment of their time, a library was eſtabliſhed many years ago by an overſeer named M'Sterling, who prevailed on the workmen to ſubſcribe for that purpoſe. Since that event the miners have been remarkable for induſtry and ſobriety of manners. the uſual concomitants of a taſte for literature; and the example has been followed with ſimilar effects at the neighbouring mines of Wanlockhead.

The iron of this county is found every where in the ſame tract with the ſtrata of coal. In many places it is imbedded between the different ſeams of that mineral, and is uſually wrought at the ſame time with it. Iron ore, that is, the metal in its richeſt ſtate, has not yet been diſcovered here in any great quantity, but ironſtone exiſts in great profuſion. It is found either in the form of beds of rock, or in collections of nodules or ironſtone balls, as they are called by the workmen, of various ſhapes, ſize, and qualities. Among theſe balls is the curious foſſil called *ludus Helmontii, ſeptuarium*, or *waxen veins*. It is of a ſpherical ſhape, more or leſs oblate or depreſſed. Above and below them are alternate ſtrata of ironſtone and ſchiſtus. They lie on their depreſſed ſides, in a regular direction, making a ſort of interrupted ſtratum, one ſtone being ſeveral inches and ſome even a foot or two diſtant from the other. The ironſtone of which they are compoſed is of excellent quality, yielding ſometimes fifty *per cent.* of iron.

The *Antiquities* in this county are not ſo numerous, in proportion to its extent, as in ſome other counties of Scotland. The Roman road, which formerly croſſed the pariſhes of Lamington and Biggar, and deſcended along the ſouth bank of the Clyde, is now only viſible in a few detached ſpots. Different parts of the upper wards, in particular, abound with excavations in the earth, or vaults which were uſed as ſtrong holds by the aboriginal inhabitants, when the haughty chieftains of Clydeſdale and Annandale were engaged in mutual hoſtilities and depredations. At Cold-chapel are the remains of a Roman ſtation, and in the ſame neighbourhood is a ſpot called Wallace's Camp. It is ſaid that a chair, which formerly belonged to that hero, is ſtill preſerved at Borrington.

Near Biggar are ſeveral artificial mounds. The church of that town is one of the moſt venerable relics of monaſtic architecture in Scotland. Here is preſerved an ancient vaſe or urn, ſuppoſed to be Roman, which was uſually appropriated to ſacred purpoſes by the Popiſh prieſts. Boghall caſtle, about a mile from this church, was formerly ſurrounded by a marſh, and acceſſible only by a cauſeway or mound of earth. The entrance is through a large and magnificent gate-way, which leads into a ſpacious court in the centre. This caſtle is flanked with towers. It was formerly the reſidence of the Flemings, earls of Wigton, and has evidently been one of the moſt extenſive and ſplendid fortreſſes in Scotland. This neighbourhood is repreſented in the popular hiſtories of ſir William Wallace, as having been the ſcene of a ſanguinary conflict between his band of patriots and the army of Edward I.

Cuthally caſtle, or, as it is vulgarly called, Cowdaily caſtle, the ſeat of the ancient family of Somerville, is ſituated in the pariſh of Carnwarth, and appears to have been formerly a place of great ſtrength. At the foot of Tintoe is an artificial mount, and near it a circle of large ſtones ſet up perpendicularly. On an adjacent farm is a place called Sheriffs' flats, where it is ſuppoſed the ſheriffs anciently held their courts. Tradition reports, that a bullock's hide, full of gold, is buried under this ſpot. Here are alſo the walls of a caſtle which belonged to the family of Lindſay. In Pittimair pariſh are the veſtiges of a large encampment, the figure of which approaches to a circular area. A ſmall fort belonging to it is ſtill diſtinctly viſible at a little diſtance from the walls. Several urns have been lately found here incloſed within four large flag ſtones. At Douglas are the remains of a caſtle belonging to the powerful family of that name. The greater part of this building was unfortunately conſumed by fire about fifty years ago. In the old church of St. Bride's, in Douglas, are a number of monuments in honour of the Douglaſes. The pariſh of Carſtairs, in the vicinity of the Clyde, contains the veſtiges of a Roman camp, the cauſeway leading to which can ſtill be traced for many miles. Pots and diſhes of different kinds, as well as various inſtruments of war and ſacrifice, have been diſcovered here. A number of coins have alſo been dug up, bearing the inſcription of Marcus Aurelius, and Marcus Antoninus. At Cleghorn is another Roman camp, ſuppoſed by general Roy to have been the work of Agricola. Beſides theſe remains of antiquity there are a number of others; as the priory of Leſmahago, the caſtles of Cudzow and Avondale, &c. but the limits of this article will not allow us to particulariſe the whole. Many of them, however, will be found either deſcribed or noticed in our acounts of the reſpective places. Rothwell caſtle, in this diſtrict, is one of the moſt magnificent ruins in Scotland. The ſtructure itſelf is ſuperb, and all the objects around have an aſpect of grandeur. The whole work is executed with ſmooth ſtone of a red colour. It is adorned with lofty towers at both

ends, and has undoubtedly been a place of confiderable ftrength.

The principal feat in Lanarkfhire is the palace of Hamilton, belonging to, and the occafional refidence of, the Hamilton family. . It is a large maffive pile, of a dull and heavy appearance, fituated in the neighbourhood of the town, from which it derived its name, and deferves notice chiefly on account of the beauty of its fcenery, and the valuable collection of paintings it contains.

Lanarkfhire has long been celebrated for its horfes, which are reckoned among the moft powerful in the world. As containing the town of Glafgow, it muft be ranked among the firft manufacturing and trading counties in Great Britain. Forfyth's Beauties of Scotland, vol. iii.

Lath

LATH, in *Building*, ſlips of wood uſed in plaſtering, tiling, and ſlating. Theſe are what Feſtus calls *ambrices;* in other Latin writers they are denominated *templa;* and by Gregory of Tours, *ligaturæ.*

In plaſtering, the narrower the laths are the better they are for the purpoſe, ſo as they are of ſufficient breadth to hold the nails, as the number of interſtices are increaſed, the lime or ſtuff will hang more readily, and the thicker they are they will be the better adapted to reſiſt violence; but then they would be much more expenſive. The laths are generally made of fir, in three, four, and five feet lengths, but may be reduced to the ſtandard of five feet. Laths are ſingle or double; the latter are generally about three-eighths of an inch thick, and the former barely one quarter, and about an inch broad. Lath is ſold in bundles; the three feet are eight ſcore to the bundle, four feet, ſix ſcore, and the five feet, five ſcore. The lath for plain tiling is the ſame as that uſed in plaſtering. Laths are alſo diſtinguiſhed into heart and ſap-laths; the former ſhould always be uſed in plain tiling, and the latter, of an inferior quality, is moſt frequently uſed by the plaſterer. Heart-of-oak laths, by the ſtatute Edw. III., ſhould be one inch in breadth, and half an inch in thickneſs: but now, though their breadth be an inch, their thickneſs is ſeldom more than one quarter of an inch; ſo that two laths, as they are now made, are but equal to one lath. According to the ſaid ſtatute, pan-tile laths are nine or ten feet long, three-quarters of an inch thick, and one and a half inch broad, and ſhould be made of the beſt yellow deal: the bundle conſiſts of twelve ſuch laths. A ſquare of plain tiling will require a bundle of laths, more or leſs, according to the pitch. The diſtance of laying laths one from another is various, differing more in ſome places than in others; but three and a half, or four inches, are uſual diſtances, with a counter-lath between rafter and rafter: but if the rafters ſtand at wide intervals, two counter-laths will be neceſſary. Laths are employed for various other purpoſes as well as plaſtering and tiling, as in filleting for ſuſtaining the ends of boards; in naked flooring and roofing; for furring up the ſurfaces; and in every kind of ſmall work, where the dimenſions of the parts do not exceed the ſcantling of laths.

In lathing for plaſtering, it is too frequent a cuſtom to lap the ends of the laths upon each other, where they terminate upon a quarter or batten, in order to prevent cutting them; but though this practice ſaves a row of nails, it leaves only a quarter of an inch for plaſter, and if the laths are very crooked, as they frequently are, there will be no ſpace whatever left to ſtraighten the plaſter: the finiſhed ſurface muſt, therefore, be rounded, contrary to the intention and to the good effect of the work; but if the ends are to be laid upon each other, they ſhould be thinned at the lapping out to nothing at the extremity, or otherwiſe they ſhould be cut to exact lengths.

Laths ſhould be as evenly ſplit as poſſible; thoſe that are very crooked ſhould not be uſed, or the crooked part ſhould be cut out; and ſuch as have a ſhort concavity on the one ſide, and a convexity on the other, not very prominent, ſhould be placed with the concave ſide outwards.

The following is the method of ſplitting laths: the lath-cleavers having cut their timber into lengths, they cleave each piece with wedges into eight, twelve, or ſixteen pieces, according to the ſcantling of the timber: the pieces thus cloven are called bolts; then, in the direction of the felt-grain, with their dowl-ax, into ſizes for the breadth of the laths: this operation they call felting; and, laſtly, with their chit they cleave them into thickneſs by the quarter-grain.

LATH *Bricks* are bricks made much longer than the ordinary ſort, and uſed inſtead of laths for drying malt upon; for which purpoſe they are extremely convenient, as not being liable to catch fire, and retaining the heat much longer than thoſe made of wood, ſo that a very ſmall fire is ſufficient after they are once heated.

Lathe

LATHE, an engine of the most extended application in the mechanic arts, for forming wood or metal into any article of a circular figure. The mode of action in a lathe is essentially different from any other method of cutting, as the work is caused to revolve in a circle, while the tool is held upon a fixed support, and presented to it to cut away any parts projecting beyond the circle described by the motion of the work. To the mechanic the lathe is an invaluable machine, as a very great proportion of all the parts of machines is formed in it, and as it is the only method of working metal which may be considered as perfect. All things which can be turned are made in the lathe, both for accuracy and expedition. The common wooden lathe, in use among wood-turners for making articles of houshold furniture, is so generally understood, that it is needless to give a minute description of it; we have, therefore, given drawings in *Plate* (*Lathe*) of a metal lathe, the most perfect of its kind, proper for turning accurate and delicate works for mathematical instruments, or machinery: it was made by Mr. H. Maudslay, London, who has a great number of different sizes, but on a similar construction, in constant use, at his manufactory for steam-engines, and other machinery, in the Westminster-road. *Figs.* 1. and 2. of the plate are a front and end elevation of the whole lathe, where A A is a strong mahogany bench, supported on iron standards B, B, which are shewn fully in *fig.* 2; beyond these are suits of drawers C, C, to contain the tools, &c.: the standards B' carry the axis D of the great foot-wheel E, which gives motion to the work when it is turned by its crank D and treadle F, on which the workman presses his foot, at intervals, to turn the wheel round. The lathe itself, which is fixed upon the bench, consists of a triangular bar G. See also *fig.* 3, which is an enlarged figure of it; it is supported on small standards *a*, *b*, *c*, fixed to the bench A by screws going through it: upon this bar the puppets H, I, and K, are fitted with perfect accuracy, and H, which is called the back puppet, can be fastened at any part of the bar by a screw beneath it; the other two puppets, I, K, are screwed down upon the standards *a* and *b*, and are connected together by a piece of metal *d* fitting upon the bar, and cast in the same piece with them: these two puppets support the mandrel, or spindle L, one having a screw with a conical steel point to enter a hole in the end of the spindle, and the other having a hard steel collar to receive the neck of the spindle, which fits it with the most perfect accuracy, to turn round freely (by a band encompassing its pulley M), but without any shake in its collar; on the end of the spindle, beyond the collar, is a small screw to fix on the work to be turned. The back puppet H has a hole through the top of it, exactly in a line with the spindle, and a steel pin *e*, with a conical point fitted into it to support the end of a long piece of work; the point is fastened by a screw *g* in the top of the puppet, and has a screw *f* behind it to force it forwards: the bar G, also, has the rest, or support, for the tool fixed upon it, by a piece of metal *g*, (*fig.* 1.) fitted upon

the bar; a ſlider is fitted upon this piece to ſlide in a direction perpendicular to the bar, and the ſame ſcrew beneath faſtens the reſt upon the bar at any place, and the ſlider at any length acroſs the bar. On this ſlider is a ſocket to receive a pin, on the top of which is a croſs-piece, formed like a T, upon which the tool is laid; this T can be adjuſted to the height of the work the tool is to be applied to, and can be faſtened at any height by the ſcrew in the ſide of the ſocket. The various kinds of work to be turned are faſtened to the end of the ſpindle, ſo as to be turned round with it, by means of what are called chucks: theſe are pieces of wood, or metal, fitted to ſcrew faſt upon the end of the ſpindle, and a hollow, like a diſh, being turned out in it; the piece of wood or metal to be turned is driven into this hollow, and thus held to be turned, by holding a tool over the T of the reſt, which is previouſly fixed cloſe to the work, and preſenting the edge to the work as it revolves by the treadle F, turning the foot-wheel, &c.: this, by its band turning the pulley M, and the work with an increaſed velocity. A chuck of this deſcription is ſhewn mounted in *fig.* 1, with what is ſuppoſed to be a plate of braſs, held in it to turn the flat face. Some chucks are flat, with holes through them, and the work is held by ſcrews againſt it; others are provided with three jaws, like a vice, which can be altogether cauſed to advance to, or recede from, the centre, by turning a ſcrew, ſo as to encompaſs a piece of work of any dimenſions. This method of chucking is adopted to form all kinds of flat or hollow work, as cups, boxes, circular rings, or plates, wheels, &c. which are, therefore, termed chuck-work; but articles of conſiderable length are ſupported at both ends, which method is called turning between centres. In this method the puppet H is ſlid along the bar to the length of the work, and fixed there by its ſcrew: the point *e* is now, by its ſcrew *f*, thruſt forwards, and its point enters a ſmall hole, previouſly drilled in the end of the work: the ſcrew *g* is now tightened, to faſten the point *e*, upon which one end of the work revolves as a centre, the other end is received into a ſquare hole in the end of a chuck ſcrewed to the ſpindle. In other caſes, the ſpindle has a chuck ſcrewed to it, terminating in a conical point ſimilar to that at *e*; this forms a ſupport for the end, and an arm, projecting from the chuck, intercepts a pin or arm fixed to the work, and by this means turns it round with the ſpindle. This method of turning between centres is employed to turn ſpindles of wheels, bolts, ſcrews, rollers, the outſides of cylinders, or any other articles of greater length than their diameter. When a piece of work is to be turned, which is larger than the lathe will admit, the bar is to be drawn out, as in *fig.* 1, and ſupported by an additional ſtandard *c* ſcrewed to the bench. In the ſame ſtate it will admit longer work.

The particular manner of holding the tool to the work is not eaſy to deſcribe in words, but is ſoon acquired by practice. The tools for braſs are ſquare or flat bars of ſteel, the ends of which are cut off obliquely, to form an edge like a chiſſel, but with a very obtuſe angle. It is held in ſuch a poſition, that its upper flat ſurface points to the centre of the work to be turned: it is to be held down as firmly as poſſible to the reſt, and advanced to the work at intervals, whenever it ceaſes to cut, by having removed all the projections of the work without the circle it deſcribes. For turning with extreme accuracy, the ſlide-reſt is a very uſeful addition to the lathe. It is a reſt with two ſliders in different directions, to one of which the tool is fixed: by means of ſcrews with handles, the ſliders and the tool can be moved in either direction, to bring the tool to the work. *Figs.* 3, 4, and 5, explain the ingenious piece of mechaniſm. N A is a piece of metal, fitted to the bar of the lathe, and provided with a ſcrew to faſten it at any place: upon the upper ſurface, which is flat, two pieces of braſs are ſcrewed, to form a dove-tailed groove, in which a ſlider, *h*, is fitted, to move with freedom and preciſion; a ſcrew, *i*, is mounted in the frame N, and is lapped into a piece projecting from the lower ſide of the ſlider, ſo that the ſcrew, when turned round by a handle fitted on its ſquare, advances or draws back the ſlider in its groove. Upon this ſlider, *h*, is a frame *k*, having at the top of it a ſlider *l*, provided with a ſcrew *m*, as the former, to move it, and carrying a piece *n*, with ſquare holes through it in two directions to receive the tool *o*, and a ſcrew at top to faſten it in. The ſlide-reſt being mounted, in the manner of *fig.* 3, upon the bar, the upper ſlider, *l*, is parallel with the ſpindle, and the lower one, *h*, perpendicular thereto. For turning flat work, the tool is put in as there ſhewn: now by turning the ſcrew, *m*, of the upper ſlider, the tool is advanced in contact with the work, which is mounted as in *fig.* 1; then by the other ſcrew, *i*, it is drawn acroſs the face of the work, turning it as it proceeds, to a perfectly flat ſurface. For turning a cylinder between centres, the tool, *o*, is put through its holder *n*, in a direction perpendicular to that ſhewn in *fig.* 3; and then the lower ſlider, *h*, is moved to adjuſt the tool to the diameter of the intended work; and the upper ſlider is moved, to carry the tool along the length of the cylinder, and cut it as it goes. The ſlide-reſt will alſo turn cones, by the following contrivance: the frame *k*, ſupporting the upper ſlider, is fitted to the lower ſlider by one pin, upon which the whole frame and upper ſlider may be turned round and faſtened at any inclination, by two ſcrews paſſing through circular grooves. By this means the upper ſlider is inclined in any angle to the ſpindle, to turn a cone either hollow or ſolid, as the tool is put into its holder in one or other direction.

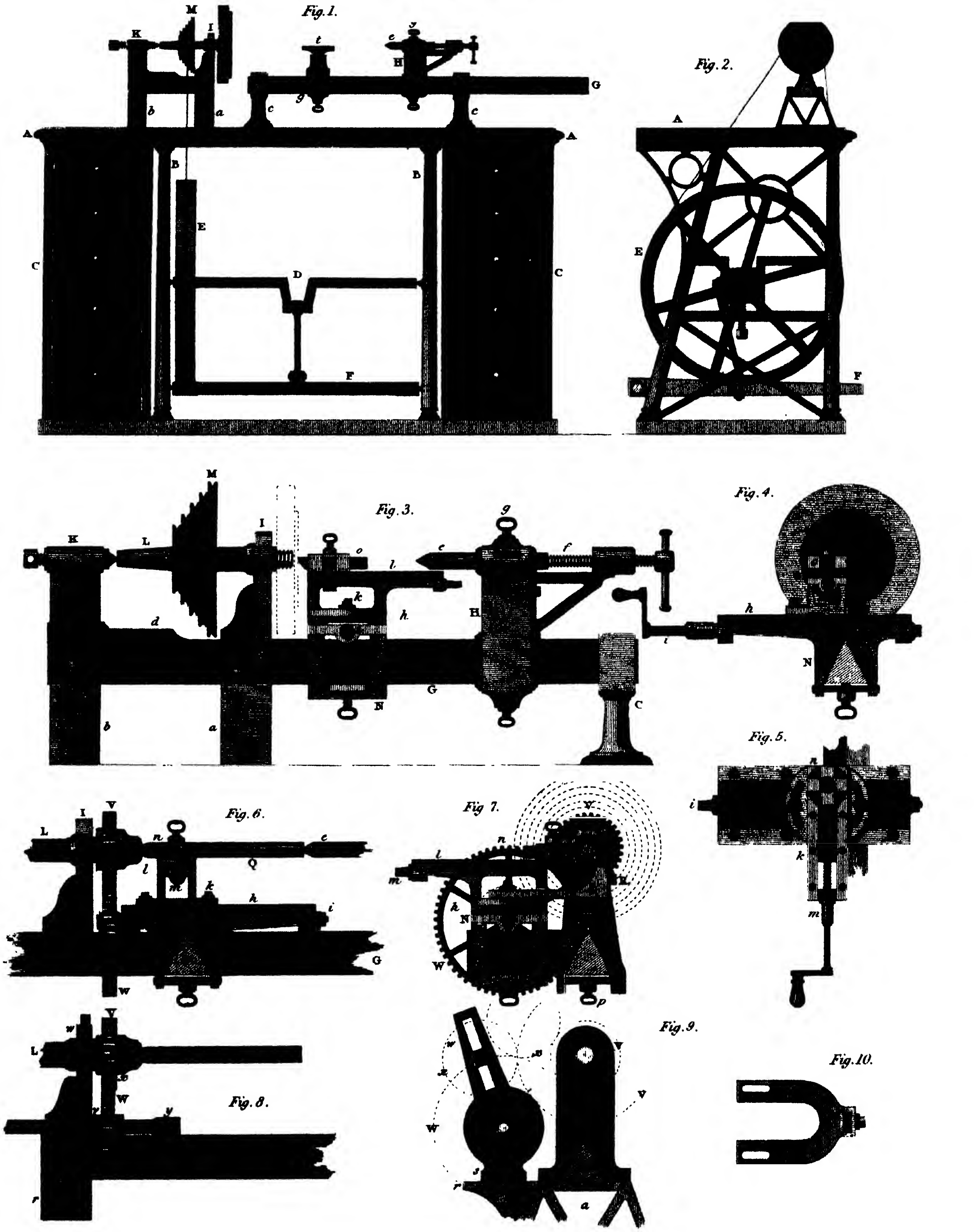
The ſlide-reſt can be made to cut ſcrews by an ingenious application, which is explained in *figs.* 6 and 7. A ſhort bar P, exactly of the ſame dimenſions as the large one, is fitted thereon, and faſtened by its ſcrew *p*. Upon this the ſlide-reſt is placed: its ſliders now ſtand in a direction perpendicular to what they did before, though on the ſame level. The ſcrew to be cut, repreſented by Q, *fig* 6, is mounted between the centres, and turned to a true cylinder by a tool put in the holder *n*, and carried along parallel to the ſpindle, by turning the ſcrew, *i*, of the lower ſlider: this being done, a cog-wheel, V, is fitted on the chuck, at the end of the ſpindle, and another, W, is attached to the end of the ſcrew, *i*, of the lower ſlider, ſo that it will be turned round at the ſame time with the ſpindle. A tool, with a point of the proper form to cut the thread of the ſcrew, is put in the holder *n*, and advanced by the ſcrew, *m*, of the upper ſlider to touch the cylinder Q. The lathe being now put in motion, the tool is moved along by the ſcrew of the lower ſlider, at the ſame time the work revolves, and upon which it traces a ſpiral groove. When it arrives at the end of the ſcrew, which it only ſcratches the firſt time, the tool is drawn back clear of the work, and the lathe turned the contrary way, to return the tool to the place where it firſt ſet out. The tool is then ſet by the ſcrew *m*, to cut deeper than the firſt time, and the ſcrew is cut over again: this being repeated four or five times, the ſcrew is completed. By this method a ſcrew of any degree of fineneſs may be cut, by merely changing the proportion of the cog-wheels, V, W, which connect the ſpindle and the ſcrew of the lower ſlider. It is plain, if theſe wheels are of equal ſize, a ſcrew will be formed of the ſame width of threads as the ſcrew of the ſlide-reſt at *i*; and if the wheel, W, on the ſcrew, is the

largeſt, the ſcrew cut will be finer; if, on the other hand, the ſmalleſt wheel is fixed on the ſcrew at W, it will cut a ſcrew of a coarſer thread than the ſcrew *i*. The lathe is provided with wheels of all the different ſizes, ſhewn by the dotted circles V, *fig.* 7, any of which may be fixed on at pleaſure, either on the ſcrew or the chuck. The ſcrew cut in this manner will have its threads inclined in a contrary direction to the ſcrew of the ſlide-reſt; and if that is a left-handed ſcrew, it will cut a right-handed ſcrew, becauſe the ſlider-ſcrew revolves in an oppoſite direction to the ſpindle. That the lathe may cut ſcrews of either kind, an intermediate cog-wheel is introduced between the two, to cauſe them to turn the ſame way. This gives another advantage, *viz.* that any two wheels may be uſed together; the intermediate wheel communicating motion from one to the other, though they are conſiderably diſtant from touching each other. The application of the intermediate wheels is explained in *figs.* 8 and 9, where *r* is a projecting ſhelf from the ſtandard *a*; upon this a piece of metal, *s*, is faſtened by a ſcrew, and a ſhort hollow ſpindle, *v*, is fitted into it, and faſtened by proper ſcrew-collars which admit its rotation; upon the end of this the cog-wheel W, which turns the ſcrew of the ſlide-reſt, is faſtened by a nut: an arm, *w*, is fitted on the ſhort ſpindle *v*, ſo as to have an angular motion round the centre: the arm has a groove in its length, in any part of which the centre pin of the intermediate wheel, *x*, can be faſtened; and by theſe two motions this wheel may be fixed at any joint, ſo as to connect the wheels of any ſize. The hollow ſpindle, *v*, is adapted to receive an arbor or axis *y*, which has a ſocket in the end adapted to the ſquare, upon the end of the ſlide-reſt ſcrew *i*: by this method the ſlide-reſt may be ſet at any part of the lathe bar; when it is required to cut a ſcrew at the end of a long bolt; the arbor *y*, forming the connection between the cog-wheel, W, and the ſcrew, for which purpoſe it ſlides through the hollow ſpindle *v*, but is cauſed to revolve with it, by a feather or fillet projecting from one ſide; the ſocket of the hollow ſpindle may be ſet and faſtened at any required diſtance from the lathe bar, and faſtened by its ſcrew; the ſlide-reſt being ſet at a correſpondent diſtance from the ſpindle of the lathe, by moving it upon the bar P, will admit a large piece of work, when a ſcrew is required to be cut upon it. R, *fig.* 7, is an iron frame, faſtened to the lower ſlider of the ſlide-reſt, to ſupport the ſcrew from bending by the preſſure of the tool, when it is long and ſlender. The frame is ſhewn in plan in *fig.* 10, where the holes are ſhewn for the two ſcrews which hold down the frame upon the lower ſlider.

The methods of holding various pieces of work in the lathes to turn them are endleſs, and depending in a great meaſure upon the ingenuity of the workman to adapt them to the particular occaſions he meets with. This ſubject, as well as the figure and manner of holding the tools, will be reſumed under the article TURNING; an art which, from the facility with which it produces ſo many beautiful forms, has become a faſhionable amuſement among gentlemen, who may require many practical inſtructions, which would be needleſs to the mechanic regularly educated in the workſhop. We ſhall alſo deſcribe the method of turning elliptic work, as well as circular.

LATHE.

by Mr. H. Maudslay.



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Lattin

LATTIN, or LATTEN, a name by which we used to call the plates of iron covered with tin, and now usually called *tin*, of which our mugs, and such other things, are made. The principal part of the work is to prepare the leaves, beat out to a proper thinness, so as that they shall readily receive the tin; for if there be but the smallest particle of dust on them, or only the slightest rust in any part, the tin will never fix there.

This smoothing of the plates is effected by steeping them in acid water, till the surface is a little preyed upon by it, and then they are scowered with sand, which makes them very smooth and fine. By this means a woman cleans more plates in an hour, than the most expert workman can do otherwise in many days. M. Reaumur, to whom the world owes the discovery of this process, mentions several waters, any one of which will succeed, but the Germans themselves use nothing but common water, made eager with rye. This they make a great secret of, but the preparation is very easy. After they have ground the rye grossly, they leave it to ferment in common water for some time; and they are thus sure of a sharp and eager menstruum, excellently fitted for their purpose. With this liquor they fill certain troughs, or tuns, and into these they put several bundles of the plates of iron: and to make the liquor more eager, and to act the better on them, they keep it in stoves, where it has little air, and is kept warm with small charcoal fires.

There are several other ways of making iron rust, as keeping it in a moist cellar, exposing it to the dew, sprinkling it with simple water, or, which is still better, with water in which sal ammoniac has been dissolved, several times a day: and in those countries where the pyrites is common, the vitriolic waters, which partake of it, will do it very well. This water may be prepared at little or no expence, only by heaping up large quantities of the pyrites, and letting it moulder in the air, then putting it into common water, and making a lixivium of it. Whichever method of rusting the plates be used, it is always necessary to scower them with sand as soon as it is done; and when they are thus cleaned, they must be immediately plunged into water, to prevent their rusting again, and they are to be left in this water till the instant in which they are to be tinned, or, in the language of the workmen, *blanched*. The people employed in this part of the operation are called *blanchers*; and the others, who assist at the cleaning of the plates, the *scalers*. The blancher makes as great a secret of his art, as the scaler does of his; and it was with great difficulty that M. Reaumur obtained it. The manner of doing it is this:

They flux the tin in a large iron crucible, which has the figure of an oblong pyramid with four faces, of which two opposite ones are less than the two others. The crucible is heated only from below, its upper part being luted with the furnace all round. The crucible is always deeper than the plates, which are to be tinned, are long; they always put them in downright, and the tin ought to swim over them. To this purpose artificers of different trades prepare plates of different shapes, but M. Reaumur thinks them all exceptionable. But the Germans use no sort of preparation of the iron, to make it receive the tin, more than the keeping it always steeped in water till the time; only when the tin is melted in the crucible, they cover it with a layer of a sort of suet, which is usually two inches thick, and the plate must pass through this before it can come to the melted tin. The first use of this covering is to keep the tin from burning: as if any part should take fire, the suet would soon moisten it, and reduce it to its primitive state again. The blanchers say, this suet is a compounded matter. It is indeed of a black colour, but M. Reaumur supposed that to be only an artifice to make it a secret, and that it is only coloured with soot, or the smoke of a chimney; but he found it true so far, that the common unprepared suet was not sufficient; for after several attempts, there was always something wanting to render the success of the operation certain. The whole secret of blanching, therefore, was found to lie in the preparation of this suet; and this he at length discovered to consist only in the first frying and burning it. This simple operation not only gives it the colour, but puts it into a condition to give the iron a disposition to be tinned, which it does surprisingly.

The melted tin must also have a certain degree of heat, for if it is not hot enough, it will not stick to the iron; and if it is too hot, it will cover it with too thin a coat, and the plates will have several colours, as red, blue, and purple; and upon the whole will have a cast of yellow. To prevent this, by knowing when the fire has a proper degree of heat, they might try with small pieces of iron; but, in general, use teaches them to know the degree, and they put in the iron when the tin is at a different standard of heat, according as they would give it a thicker or thinner coat. Sometimes also they give the plates a double layer, as they would have them very thickly covered. This they do by dipping them into the tin, when very hot, the first time, and when less hot, the second. The tin, which is to give the second coat, must be fresh covered with suet, and that with the common suet, not the prepared. Philos. Trans. N° 406, p. 634. See TIN.

Laundry

LAUNDRY, as if *Lavanderie*, Fr. the room in which clothes are washed; or, in a more restricted and appropriate sense, as the term is used in the subsequent article, it denotes the place where clothes are mangled, dried, and ironed. Under this head we shall include the *wash-house*, as it is necessarily connected with the laundry. Washing and getting up linen are employments of great importance in most families, and they have engaged the attention of many ingenious mechanics, who have contrived various washing-machines for the abridgment of labour and expence in this department of domestic economy. Most of the machines hitherto used are objectionable on many accounts, but principally because they operate by *friction*, instead of *pressure*. When the linen is properly prepared for washing, it may be thoroughly cleansed by *pressure* only. Rubbing it with the hands, or by any machine that operates by friction, injures it more than the wear it sustains in actual use. Hence it follows that the best method of cleansing foul linen is, first, to prepare it for the operation by soaping it where necessary, and putting it into soak for at least twelve hours. This will loosen the filth, and decompose the grease and other matter with which it is soiled, and it will then be readily removed by alternately soaking, and squeezing or pressing. The desideratum, therefore, is, to contruct a machine that would, by a rotative motion, or an up-and-down stroke, (like pumping) alternately press and saturate the linen with

the ſuds, and laſtly with clear water. The machine that comes neareſt to this, of any that has fallen under our notice, is one invented by Mr. Gould.

We ſhall now deſcribe a waſh-houſe and laundry, conſtructed upon ſcientific principles by John Bentley, eſq. the preſent poſſeſſor of Highbury Houſe, near London, being the completeſt of the kind we have met with.

The waſh-houſe is 24 feet long, nine feet broad, and eight feet high. It is furniſhed with a filtering machine, a ciſtern for filtered water, two coppers, a copper cullender, a jack with pullies, ſix waſhing tubs, a ſtone ſink, a table, a wringing machine, and a pump of hard water.

The floor is rough Yorkſhire-ſtone, laid upon a ſharp current. Over two-thirds of the roof is a lead ciſtern containing 40 hogſheads of rain water, ſupplied from the adjoining buildings. The other third of the roof is conical, ſurmounted with a cylinder for a ſteam-vent, which opens and ſhuts at pleaſure. When open, beſides emitting the ſteam, it admits both light and air. The ciſtern for filtered water holds 200 gallons, and ſupplies, by pipes and cocks, the copper tubs and ſink.

The firſt copper is fixed ſo that the top of it is level with the bottom of the ciſtern, and the bottom of it is level with the top of the other copper, and the tops of the tubs and ſink, all which it ſupplies with hot water. The tubs, coppers, and ſink, are ſupplied with cold water from the ciſtern. Each of the tubs has a braſs plug at bottom, to diſcharge the foul water. A nine-inch board runs along the front of the tubs and ſink on the ground, to prevent the ſplaſhing of the water when diſcharged. Each tub is furniſhed with a ſmall wooden ſtrainer for ſoap.

The ſecond copper is for boiling the linen, and has a copper cullender to hold the linen, which is drawn up by the jack and pullies. The jack has a paul and ratchet wheel to keep the cullender ſuſpended over the copper till the water is drained from the linen into the copper, which can then be turned out altogether into the rinſing-tub. By this contrivance, the uſual mode of poking the linen out with a ſtick (which frequently damages it) is avoided. At the bottom of this copper is a large braſs cock for diſcharging the ſuds when they are done with.

Though the ſix tubs are ſupplied with both hot and cold water, there are only ſix cocks to the whole, one cock ſupplying two tubs, by means of a ſcrew-joint in the nozzle, which turns at pleaſure to either tub. There is alſo a ſcrew-joint between the key and pipe in each cock, by which means it can at any time be repaired without the aſſiſtance of the plumber.

The filtering machine performs its operation by aſcent. It has three cocks in one pipe. The uppermoſt is for regulating the quantity of water to be filtered, which can be varied at pleaſure from 50 to 500 gallons in a day. The other is for cleanſing the machine when ſaturated with filth, which is accompliſhed by only turning the cock, and will, in a few minutes, be as clean as it was at firſt, the mud, &c. being diſcharged at the third or middle cock, which alſo ſerves to draw unfiltered water when required. Under the ciſtern is a receptacle for coals, and under the filtering machine a place for pails and mops. Both ciſterns have a ſurplus water-pipe to prevent running over, and in which are alſo plugs to diſcharge all the water when needful.

The table hangs to the wall, and may be put up and down at pleaſure. It is for ſorting and ſoaping the foul linen, &c.

The laundry adjoining the waſh-houſe is 18 feet ſquare, and 11 feet in height. It has two windows in front. The floor is level, of rubbed Yorkſhire-ſtone, laid upon brick piers, to keep it perfectly free from damp. It is furniſhed with one of Baker's large mangles; an ironing-board 12 feet by three feet, with four large drawers for the ironing-cloth, iron-holders, &c. with room for the clothes-baſkets underneath; a ſtove or drying-cloſet, eight feet by ſix feet; a furnace for heating the cloſet and the irons, and a place for coals under the floor, cloſe by the furnace. The cloſet contains four wooden horſes, each with five rails or bars. Each horſe runs in and out of the cloſet upon two ſmall iron wheels, upon an iron rail-way. One horſe holds ſix ſhirts, or a proportionable quantity of other linen, and the whole will dry off as much and as ſpeedily as ſix women can waſh in ſucceſſion. It hardens the linen after being ironed, and is alſo uſeful for airing feather beds, &c. The linen, whilſt drying, is kept free from ſmoke and duſt, and there never can be any ſteam in the room.

The furnace for heating it is ſimilar to thoſe under coppers or in a hot-houſe, immediately over which, before it enters the flue to the cloſet, is an iron oven for heating the irons. The flue is continued round the bottom of the cloſet, and carried up the end of the building. The top of the horizontal part of the flue is of caſt-iron plates; iron being a good, and brick a bad conductor of heat. A few inches above theſe iron plates, the iron rail-way before mentioned is laid, between which and the flue there is a flooring of wire work. This prevents any accident from the caſual falling of linen upon the flues, but does not impede the aſcent of warm air. Level with the rail-way, inſide the cloſet, there is an opening 15 inches ſquare, communicating with the external air. The cieling of the cloſet is in the form of a hopper, terminating in a funnel of the ſame diameter (15 inches) as the external air-vent. Both theſe vents are furniſhed with a ſliding door, which opens and ſhuts, as required, by pulley cords.

The principle upon which it acts is by heating it to a degree ſufficient to excite a ſtrong evaporation from the wet linen, and carrying off the moiſture by means of the two vents. During the time of its acquiring this heat, both the vents, and alſo the horſes, are kept cloſely ſhut, ſo that the cloſet is nearly air-tight. As ſoon as the proper degree of heat is obtained, both the vents are to be opened, when a ſtrong current of air ruſhes in at the loweſt, carrying up all the vapour from the linen through the upper vent or funnel, when the drying will be very ſpeedily completed. The linen is then removed, a freſh ſupply put in, and the operation repeated as before, beginning by cloſely ſhutting all up.

Beſides the diſpatch and economy attending this waſh-houſe and laundry, the health and comfort of thoſe employed in them are greatly promoted, by being entirely free from the pernicious effects of damp vapour, and in not being incommoded by any extra heat in hot weather.

Since this article was written, the gentleman above mentioned has made a conſiderable improvement in the waſh-houſe. He has conſtructed an apparatus for performing the operation by *ſteam*. Although it is not yet (December 1811) quite completed, it is ſufficiently ſo to have aſcertained by experiment, that every ſpecies of *white* linen may be better cleanſed this way than it is poſſible to do it by the hands, or any machine hitherto invented.—We ſay *white* linen, becauſe the operation proves to be ſo powerful, that it diſcharges the colour from all dyed and printed articles that have been tried with it.

At the end of the waſh-houſe a ſtrong iron-boiler is fixed three feet ſix inches long, one foot eight inches wide, and two feet nine inches deep, with fittings up the ſame as thoſe for ſteam-engines, *viz.* a feeding-pipe with regulator, a

mercury gauge-tube, a three-inch ſteam-tube, two obſervation cocks, a ſafety valve, and a diſcharging pipe. From the ſteam-tube, a pipe of 1½ inch bore is continued the whole length of the building; and from this main ſteam-pipe, others of ſmaller dimenſions, from ⅛ to ¾ inch diameter, are laid on the different ſteaming veſſels. Theſe may be either of wood, tin, or copper; but the latter is certainly beſt, for the action of ſteam is ſo powerful, that it will ſoon render both wood and tin uſeleſs. They muſt be fitted with a looſe grating inſide, about two inches from the bottom; a cock at one end, to admit the ſteam; and another at the other end, quite at the bottom, to diſcharge the foul water. The proceſs is as follows: Soap the linen where it is very dirty, and put it to ſoak; then place the linen upon the grating in the ſteam veſſel; cover it up, and turn on the ſteam. The diſcharging cock muſt be occaſionally opened, to draw off the condenſed ſteam; and when it is found to come off perfectly clear, which it will do in half an hour, or leſs, the operation is finiſhed, and the articles will come out perfectly clean, and moſt beautifully white.

By this ſimple and eaſy proceſs, the drudgery of waſhing is entirely done away; and the ſaving in time, ſoap, and other expences, is greater than can well be conceived. The ſaving of water in many ſituations is a matter of conſequence; but what is of ſtill more importance, the linen will laſt double the time it otherwiſe would do: for as there is neither preſſure nor friction, it cannot be injured in this proceſs.

Waſhing by ſteam has been practiſed, but never before by this method. The way it has been done has been by ſteaming the linen *in the ſuds*. Hence it is evident that the filth that is forced out of the linen is mixed with the ſuds, and is again diſperſed equally all through the linen; ſo that repeated changes of ſoap and water muſt be had recourſe to, before the linen is made thoroughly clean. But by this new proceſs, the linen being put into the ſteaming veſſels, without any other liquor than it retains on being taken out of the ſoaking tubs, every particle of matter which is diſlodged from it inſtantly ſubſides to the bottom of the veſſel, and never can again come in contact with the linen. Our readers muſt excuſe the prolixity of this article, on account of its great importance and uſefulneſs in domeſtic economy to every family.

Note.—The boiler above deſcribed alſo heats an hot-houſe in an adjoining garden, beſides boiling a copper, and thus does the work of ſix fires.

Lavoisier

LAVOISIER, ANTHONY LAWRENCE, in *Biography*, a diftinguifhed chemical philofopher, was born at Paris, on the 13th of Auguft 1743. His father, who was a man of opulence, fpared no expence in beftowing upon him the advantages of a liberal education; and he difplayed very early proofs of the extent and fuccefs of his ftudies, efpecially in the circle of the phyfical fciences. In the year 1764, the French government propofed a prize queftion, relative to the beft method of lighting the ftreets of a large city. Lavoifier prefented a differtation on the fubject, which he difcuffed upon the moft enlarged and philofophical views. This was not only highly approved, and printed at the expence of the Academy of Sciences, but obtained for him the prefent of a gold medal from the king, which was delivered to him by the prefident of the Academy, at a public fitting, in April 1766. Two years afterwards, he was admitted a member of that learned body, of which he was conftantly one of the moft active and ufeful affociates. About the fame time, he was occupied in experimental refearches on a variety of fubjects; fuch as the analyfis of the gypfum found in the neighbourhood of Paris; the cryftallization of falt; the properties of water; and in exploring the phenomena of thunder, and of the aurora borealis: and he diftinguifhed himfelf by feveral differtations on thefe and other topics, practical and fpeculative, which appeared in different periodical works. In the Memoirs of the Academy for 1770 were publifhed his obfervations on the nature of water, and on the experiments which had been fuppofed to prove the poffibility of its converfion into earth. He proved, by a careful repetition of thefe experiments, that the earthy depofit, left after repeated diftillations of water, proceeded folely from an abrafion of the veffels employed. Lavoifier performed feveral journies into various parts of France, in company with M. Guettard; in the courfe of which he collected a ftore of materials for a lithological and mineralogical hiftory of that kingdom, which he ingenioufly arranged in the form of a chart. Thefe materials were the bafis of a great work on the revolutions of the globe, and on the formation of the ftrata of the earth: two interefting fketches of which were

printed in the Memoirs of the Academy for the years 1772 and 1787.

In fact, M. Lavoifier devoted his whole time and fortune to the cultivation of the fciences, the boundaries of which he feemed, by fuch an union of zeal, talent, and wealth, deftined to extend. About this period, a new mine of experimental refearch, which promifed the moft curious and interefting refults, had been opened out by the genius of Dr. Black, and already purfued with much fagacity and induftry by Dr. Prieftley.—We allude to the difcovery of the properties of certain aëriform fubftances, gafes, or (as they have been called) factitious airs, which had hitherto efcaped the attention of chemical inquirers. M. Lavoifier, ftruck with the beauty and importance of thefe difcoveries, entered into the fame field of refearch with all the fcientific ardour by which he was characterized: and here the advantage of his ample wealth was manifeft; for he conducted his experiments upon a large fcale, with coftly inftruments of the moft improved conftruction. The refult of this courfe of experimental inquiry he gave to the world in 1774, in his "Opufcules Chymiques," which contained not only a clear and elegant view of all that had hitherto been done, in regard to gafeous or aëriform fluids, but alfo feveral original experiments, remarkable for their ingenuity and accuracy.

The exiftence of a gafeous body, in a *fixed* or folid ftate, in the mild alkalies and alkaline earths, which, when expelled from thefe fubftances, affumed an aërial form, and left them in a cauftic ftate, as well as its production during the combuftion of fuel, had been demonftrated by Dr. Black; and Bergman had fhewn that this air poffeffed acid properties. Dr. Prieftley had alfo fubmitted it to various experiments in the year 1767; but no progrefs had been made in afcertaining the real conftituent parts of this acid gas, or fixable air. The honour of this difcovery was left for Lavoifier; who, in 1772, by expofing a piece of charcoal, inclofed in a glafs veffel, to the action of a *lens*, difcovered that part of the charcoal was confumed, that a diminution of air had taken place in the receiver, and that the refidue poffeffed the properties of the fixable air:—whence he concluded that charcoal was one of the conftituent parts of this gas. The combuftible nature of the diamond having been already proved by Macquer, d'Arcet, and others, Lavoifier was induced to fubmit this fubftance to the fame treatment as the charcoal in the former experiment; and he found that precifely the fame refults took place: whence he inferred, that there exifted a great analogy between charcoal and diamond. Both thefe conclufions have been amply confirmed by fubfequent experiments; they were in every refpect important; and feem, together with the facts previoufly known, of the production of acids by the combuftion of fulphur and phofphorus, to have given the firft hint to Lavoifier of his fubfequent general theory of the formation of acids.

Lavoifier now turned his experimental refearches to the fubject of the *calcination* (as it was then termed, from its apparent fimilarity to the procefs of making *lime*) of metals. It had already been fhewn by Rey and Homberg, that metals acquire an augmentation of weight during calcination. This additional weight was attributed by the latter to the fixation of heat and light; but was fuppofed by the former to proceed from the fixation of a part of the air. M. Lavoifier publifhed the refult of his inveftigation of this curious fubject in 1774, in a memoir on the calcination of tin in clofe veffels, in which he demonftrated the following very important facts. He fhewed, 1, that a given quantity of air was requifite for the calcination of a given quantity of tin; 2, that a part of the air is abforbed during this procefs, by which not only the bulk, but the weight of the air is diminifhed; 3, that the weight of the tin is increafed during the fame procefs; and, 4, that the weight acquired by the tin is exactly equal to that which is loft by the air.

Thus by a few fimple, accurate, and well-chofen experiments, Lavoifier had apparently arrived at the legitimate inference, that during the procefs of the formation of acids, whether with carbonaceous matter, fulphur, or phofphorus, and alfo during that of the calcination of metals, an abforption and fixation of air take place, and thus he gained a glimpfe of principles, in the view of which his fingular fagacity in devifing experiments, and his accuracy in executing them, would in all probability have alone conducted him to thofe brilliant refults, to which the active genius of Dr. Prieftley fo materially contributed. The fynthetic proofs only of this union of air with the bafe had been as yet afcertained: but Dr. Prieftley firft furnifhed the analytic proof, by diffevering the combination; a difcovery which at once advanced the nafcent theory of Lavoifier, and, in his hands, became the fource of more than one important conclufion. In Auguft 1774, Dr. Prieftley difcovered, that by heating certain metallic calces, efpecially the calcined mercury, (the precipitate *per fe*, as it was then called,) a quantity of air was feparated, while the mercury refumed its metallic form; and this air, which he found was much purer than that of the atmofphere, he called, from the theory of the time, *dephlogifticated* air. The fucceeding winter he fpent at Paris, and communicated to Lavoifier, and the other philofophers there, his recent difcovery: and the importance of this intelligence to the views of Lavoifier was manifeft in a memoir publifhed by him in the following year, 1775, on the nature of the principle which combines with metals during their calcination. In this paper he fhewed, in conformity with the experiments of Dr. Prieftley, that the mercurial precipitate *per fe*, by being heated in a retort, gives out a highly refpirable air, (fince called *oxygen*,) and is itfelf reduced to the metallic ftate; that combuftible bodies burn in this air with increafed brilliancy; and that the fame mercurial calx, if heated with charcoal, gives out not the pure air, but fixed air:—whence he concluded that fixed air is compofed of charcoal and the pure air. It has, therefore, fince been called *carbonic acid*.

A fecond very important confequence of Dr. Prieftley's difcovery of the pure or vital air, was the analyfis of the air of the atmofphere: which was accomplifhed by Lavoifier in the following manner. He included fome mercury in a clofe veffel, together with a known quantity of atmofpheric air, and kept it for fome days in a boiling ftate: by degrees a fmall quantity of the red calx was formed upon the furface of the metal; and when this ceafed to be produced, the contents of the veffel were examined. The air was found to be diminifhed both in bulk and weight, and to have been rendered altogether incapable of fupporting combuftion or animal life: part of the mercury was found converted into the red calx, or precipitate *per fe*; and, which was extremely fatisfactory, the united weight of the mercury and the precipitate exceeded the weight of the original mercury, by precifely the fame amount as the air had loft. To complete the demonftration, the precipitate was then heated, according to Dr. Prieftley's firft experiment, and decompofed into fluid mercury and an air, which had all the properties of vital air; and this air, when mixed with the unrefpirable refidue of the original air of the receiver, compofed an elaftic fluid poffeffing the fame properties as atmofpherical air. The vital air was afterwards made the fubject of various experiments in refpect to the calcination of metals, to the combuftion and converfion of fulphur and phofphorus into

acids, &c. in which processes it was found to be the chief agent. Hence it was named by Lavoisier *oxygen* (or generator of acids), and the unrespirable residue of the atmosphere was called *azot*, (*i. e.* incapable of supporting *life*.)

The new theory thus acquired farther support and consistency: oxygen appeared to be one of the most active and important agents of chemistry and of nature; combustion, acidification, and calcination, (or, as it was now called, *oxydation*. the calces being also termed *oxyds*, *i. e.* something approaching to, or resembling acids,) were proved to be processes strikingly analogous to each other; all according in these points, that they produced a decomposition of the atmospheric air, and a fixation of the oxygenous portion in the substance acidified or calcined.

Time alone seemed now requisite to establish these doctrines, by exemplifying them in other departments of chemical research. In the year 1777, six memoirs were communicated to the Academy of Sciences by Lavoisier, in which his former experiments were confirmed, and new advances were made to a considerable extent. Our countrymen, Black and Crawford, in their researches respecting latent heat, and the different capacities of bodies under different circumstances, had laid a solid foundation, on which the doctrines of combustion, resulting from the foregoing experiments, might be perfected, and the cause of the light and heat connected with it might be explained. The first mentioned philosopher, Dr. Black, had shewn, that a solid, when it is made to assume a liquid form, and a liquid, when it assumes the form of vapour, absorbs or combines with, and renders latent, a large portion of heat, which is again parted with, becomes free and cognizable by the sense of feeling, and by the thermometer, when the vapour is again condensed into a liquid, and the liquid becomes solid. In like manner, it was now said by Lavoisier, during the process of combustion, the oxygen, which was previously in a gaseous state, is suddenly combined with the substance burnt into a liquid or solid. Hence all the latent heat, which was essential to its gaseous state, being instantaneously liberated in large quantity, produces flame, which is nothing more than very condensed free heat. About the same time, the analogy of the operation and necessity of oxygen in the function of respiration, with the preceding hypothesis of combustion, was pointed out by Lavoisier. In the process of respiration, it was found that, although atmospheric air is inhaled, carbonic acid and azot are expired. This animal operation, said Lavoisier, is a species of slow combustion: the oxygen of the air unites with the superfluous carbon of the venous blood, and produces carbonic acid, while the latent or combined *caloric* (the matter of heat) is set free, and thus supplies the animal heat. Ingenious and beautiful, however, as this extension of the analogy appeared, the subject of animal temperature is still under many obscurities and difficulties.

The phenomena of chemistry, however, were now explicable upon principles more simple, consistent, and satisfactory than by the aid of any former theory; and the Lavoisierian doctrines were every where gaining ground. But there yet remained a formidable objection to them, which was derived from a circumstance attending the solution of metals in acids; to wit, the production of a considerable quantity of inflammable air. If sulphuric acid (formerly called vitriolic acid, or oil of vitriol) consists only of sulphur and oxygen, it was said, and bar iron is nothing more than this metal in a simple state, how does it happen, that when these two substances, with a little water, come in contact, they should produce a large quantity of inflammable air during their re-action? This objection was unanswerable, and appeared to be fatal to the whole theory: but it was most opportunely converted into an argument in its favour, by the great discovery of the decomposition of water, made by Mr. Cavendish; who resolved that element, as it was formerly esteemed, into oxygen and inflammable air. The latter has since, therefore, been called *hydrogen*, or generator of water. This experiment was repeated with full success by Lavoisier and his associates in 1783; and the discovery was farther established by a successful experiment of the same chemists, carried on upon a grand scale, in which, by combining the oxygen with hydrogen, they produced water, and thus adding synthesis to analysis, brought the fact to demonstration.

This new view of chemical phenomena, together with the immense accession of new compounds and substances, which the labours of modern experimentalists had brought to light, appeared to demand a correspondent alteration in the nomenclature. Accordingly, a committee of some of the ablest of the French chemists, of whom Lavoisier was the most conspicuous, undertook the arduous task, and produced a regular system of nomenclature, derived from the Greek language, which, although far from being faultless, and notwithstanding much opposition with which it was at first treated, has become the universal language of chemical science, and has been adopted even in pharmacy and medicine. His work, entitled "Elemens de Chymie," which was published in 1789, was a model of scientific composition.

We have hitherto viewed M. Lavoisier principally as a chemical philosopher, in which character he has founded his great claims to the respect and admiration of posterity. But the other arts and sciences are indebted to him for considerable services which he rendered them, both in a public and private capacity. In France, more than in any other country, men of science have been consulted in matters of public concern; and the reputation of Lavoisier caused him to be applied to, in 1776, to superintend the manufacture of gunpowder, by the enlightened minister Thurgot. By the application of his chemical knowledge to this manufacture, he was enabled to increase the explosive force of the powder by one fourth; and while he suppressed the troublesome regulations for the collection of its materials from private houses, previously adopted, he quintupled the produce. The Academy of Sciences received many services from his hands. In addition to the communication of forty papers, relative to many of the most important subjects of philosophical chemistry, which were printed in the twenty volumes of Memoirs, from 1772 to 1793, he most actively promoted all its useful plans and researches, being a member of its board of consultation, and, when appointed to the office of treasurer, he introduced order into its accounts, and economy into its expenditure. When the new system of measures was proposed, he contributed some new and accurate experiments on the expansion of metals. The national convention consulted him with advantage concerning the best method of manufacturing assignats, and of securing them against forgery. Agriculture early engaged his attention, and he allotted a considerable tract of land on his estate in the Vendome, for the purpose of experimental farming. The committee of the constituent assembly of 1791, appointed to form an improved system of taxation, claimed the assistance of his extensive knowledge; and he drew up, for their information, an extract of a large work on the different productions of the country and their consumption, for which he had been long collecting materials. This was printed by order of the assembly, under the title of "Richesses Territoriales de la France," and was esteemed the most valuable memoir on the subject. In the same year, he was appointed one of the commissioners of the national treasury; and he introduced

into that department ſuch order and regularity, that the proportion between the income and the expenditure, in all the branches of government, could be ſeen at a ſingle view every evening. This ſpirit of ſyſtematic and lucid arrangement was, indeed, the quality by which he was peculiarly diſtinguiſhed, and its happy influence appeared in every ſubject which occupied his attention.

The private life of this diſtinguiſhed perſon was equally eſtimable with his public and philoſophical character. He was extremely liberal in his patronage of the arts, and encouraged young men of talents in the purſuit of ſcience. His houſe became a vaſt laboratory, where philoſophical experiments were inceſſantly carrying on, and where he held converſaziones twice a week, at which all the votaries of learning and ſcience, foreigners as well as Frenchmen, aſſembled. In his manners M. Lavoiſier was mild, affable, and obliging; a faithful friend and huſband, a kind relation, and charitable to the poor upon his eſtates; in a word equally claiming eſteem for his moral qualities, as for thoſe of his underſtanding.

The time was arrived, however, when diſtinction even by his talents and worth was ſo far from ſecuring public reſpect, amid the tumults of the revolution, that it became a ſource of danger, and, when joined with wealth, was almoſt certainly fatal. All thoſe eſpecially, who had held any ſituation under the old adminiſtration, particularly in the financial departments, were ſacrificed during the murderous reign of Robeſpierre, to the popular odium. Lavoiſier was ſeized and thrown into priſon, upon ſome charges fabricated againſt himſelf and twenty-ſeven other farmers-general. During his confinement he foreſaw that he ſhould be ſtripped of all his property; but conſoled himſelf with the expectation that he would be able to maintain himſelf by the practice of pharmacy. But a more ſevere fait awaited him: he was capitally condemned, and dragged to the guillotine, on the 8th of May, 1794.

The name of Lavoiſier will always be ranked among the moſt illuſtrious chemiſts of the preſent age, when it is conſidered what an extenſive and beneficial influence his labours have had over the whole ſcience. It has been ſaid, indeed, that if he be eſtimated on the ſcore of his actual diſcoveries, not only Scheele and Prieſtley, and Cavendiſh, but many more, will ſtand before him. But he poſſeſſed in a high degree that rare talent of diſcernment, by which he detected analogies, which others overlooked, even in their own diſcoveries, and a ſagacity in deviſing and an accuracy in completing his experiments, for the purpoſe of elucidating every ſuggeſtion which he thus acquired, ſuch as few philoſophers have poſſeſſed. No one who did ſo much, probably ever made ſo few unſucceſsful or random experiments. It was the ſingular perſpicuity, ſimplicity and order to which he reduced the phenomena of chemiſtry, that claimed for his theory the general reception which it met with, and occaſioned the abandonment of thoſe doctrines which prejudice and habit conſpired to ſupport. Subſequent diſcoveries, however, and more eſpecially thoſe numerous facts which the genius of Mr. Davy has lately brought to light, through the medium of that moſt powerful agent of decompoſition, galvaniſm, have rendered ſeveral modifications of the Lavoiſierian theory neceſſary, and bid fair to produce a more general revolution in the language and doctrines of chemiſtry.

M. Lavoiſier married, in 1771, the daughter of a farmer-general, a lady of pleaſing manners and conſiderable talents, who partook of her huſband's zeal for philoſophical inquiry, and cultivated chemiſtry with much ſucceſs. She engraved with her own hand the copper plates for his laſt work. Mad. Lavoiſier has ſince given her hand to another eminent philoſopher, count Rumford. Gen. Biog. Hutchinſon's Biog. Med.

Lead

LEAD, in *Mineralogy*, *Plumbum*, Lat.; *Plomb*, Fr.; *Bley*, Germ.; *Saturnus*, Alchem. The colour of lead is of a blueiſh-white; when tarniſhed, it becomes yellowiſh-white, then blueiſh, and at laſt blueiſh-black. Luſtre, when untarniſhed, 3; hardneſs, 5; and ſpecific gravity ſomewhere between 11 and 12. According to Briſſon, it was 11.352; and a ſpecimen tried by Gellert, which was found at Freyburg, was eſtimated at 11.445. Next to gold, platina, and mercury, it is the heavieſt metal, being upwards of eleven times heavier than an equal bulk of water. (See *Specific* GRAVITY.) The heavieſt is reckoned the beſt. It ſtains paper and the fingers. Next to tin, it is the moſt fuſible of all the metals. It is ſoluble in moſt of the acids, though more readily ſo in the nitrous diluted than the others. By expoſure to the moiſt atmoſphere, it ruſts or oxyds. It is malleable and unelaſtic, and its oxyd is eaſily fuſible into a tranſparent yellow glaſs. Having given this general deſcription, we ſhall now conſider the ſeveral combinations under which it is found in nature.

Ores of Lead.

Sp. 1. *Lead Glance. Bleiglanz.* This ſpecies contains two ſubſpecies: (1) *Common lead-glance*, the colour of which is of a lead-grey, of different kinds of intenſity; in ſome varieties it inclines to a blackiſh caſt. The lead-grey frequently contains the greateſt proportion of ſilver. It ſometimes preſents ſuperficially an irideſcent tarniſh. It occurs maſſive, diſſeminated, in membranes, in angular pieces, and in grains: ſometimes it is met with reticulated, ſpecular, corroded, and amorphous; ſeldom cylindrical, but often cryſtallized. The cryſtalline form exhibits ſeveral varieties: 1, in the ſhape of a cube, in which the planes are either ſtraight or ſpherical convex; 2, the cube having angles more or leſs deeply truncated; 3, the cube having its edges and angles truncated at the ſame time, but of theſe the latter the moſt deeply; 4, octahedron, either perfect or truncated on all its angles; 5, octahedron having its angles and edges truncated at the ſame time; 6, rectangular four-ſided priſms, acuminated on both extremities by four planes, which are ſet on lateral edges; 7, ſix-ſided priſms, acuminated by four planes; 8, three-ſided tables, in which the terminal planes are bevelled. The cryſtals are uſually ſmall, or at moſt middle-ſized, either grouped on one another, implanted, or ſolitary. The planes of the cryſtals are ſometimes ſmooth, ſometimes druſy, and ſometimes rough. Internally it alternates from ſpecular ſplendent to gliſtening; on the external ſurface it is leſs bright, but its luſtre is metallic. Its fracture is more or leſs perfect foliated, and its fragments are cubical. In maſs it is often compoſed of granular, and rarely of lamellar diſtinct concretions, which are much grown together, and whoſe fracture has a radiated aſpect. It is ſoft, perfectly ſectile, eaſily frangible, and the ſpecific gravity is from 6.2 to 7.8 nearly. Before the blowpipe it flies to pieces, and emits a ſulphureous odour. It is eaſily fuſible, and may be readily reduced on coal before the blowpipe. When it is alternately heated and cooled, it at length diſappears entirely; and if it contain ſilver, a globule of that metal remains behind. According to Vauquelin, lead-glance contains the following ingredients:

	From Kirſchwald, in Deux Ponts.	Kampſtein.	Ecklerberg.	Kantenbach.	Cologne.
Lead - - - -	54	69	68.69	64	63.1
Sulphur - - - -	8	16	16.18	18	12.
Carbonated lime and ſilex	38	15	16.13	18	19.67
Oxyd of iron - -	0	0	0	0	3.33
	100	100	101	100	98.1

Dr. Thomſon gives the following as the reſult of his experiments:

Lead - -	85.13
Sulphur - -	13.02
Oxyd of iron -	0,5
	98.65
Loſs	1.35
	100

Hence, as is evident from the above tables, the proportion of lead varies from 54 to rather more than 85 *per cent.* The proportion of ſilver varies conſiderably alſo; and it appears to have an effect on the external aſpect of the varieties. It ſometimes alſo contains a ſmall portion of iron; and gold has even been found in lead-glance. It is, next to pyrites, the moſt common of metallic ores, and is found in beds and veins in primitive, tranſition, and ſecondary mountains. It occurs almoſt always with blende and calamine, with which it appears to have a ſtrong geognoſtic affinity. It is frequently accompanied with ſilver ores, and ſometimes with copper ores. To mention all the places in which it is found, would be to mention almoſt all the known mineral diſtricts in the world. It is very abundant in Germany, and alſo in many places in our own country. The lead-mines in Britain are ſituated in Cornwall, Devonſhire, and Somerſetſhire, in Derbyſhire, Durham, Lancaſhire, Cumberland, and Weſtmoreland; in Shropſhire, in Flintſhire, Denbighſhire, Merionethſhire, and Montgomeryſhire; at the lead-hills in Scotland, on the borders of Dumfriesſhire and Lanarkſhire, in Ayrſhire, and at Strontian in Argyleſhire. Lead-glance is alſo found at Konigſberg in Norway; in various parts of Lapland, and in Denmark and Sweden; in ſeveral diſtricts of Saxony, Hungary, Tranſylvania; in France, Italy, and Spain. Moſt of the lead of commerce is procured from this ore: it is alſo uſed without farther preparation in the potteries for coarſe work, and alſo in the ſmelting of ſilver ores. Lead-glance is now generally uſed as a ſcientific name, in preference to the leſs ſignificant but common one *galena*, on account of its luſtre, which forms a ſtriking feature in the external aſpect of this mineral. (2) The ſecond ſubſpecies

is *compact lead-glance*. The colour of this is very fimilar to that of the common lead-glance. It occurs in mafs, diffeminated, and fpecular. The latter is externally fmooth, fhining, and fplendent; internally it is glimmering, and its luftre is metallic. Its fracture is even. It acquires a polifh by friction; its ftreak is fhining, almoft fplendent; not fo eafily frangible as the preceding fubfpecies; but agrees with it in the other characters. Its fpecific gravity is about 7.4. It occurs in veins, and is ufually accompanied with the common lead-glance. When the two fubfpecies occur together, the compact always forms the fides of the vein, and this probably owing to its having been in a lefs perfect ftate of folution. It is accompanied with black blende, common iron pyrites, copper pyrites, quartz, and heavy fpar. It is found in the lead-hills in Lanarkfhire, and in Derbyfhire; in divers parts of Germany, and in the valley of Chamouni in Switzerland.

Sp. 2. *Blue lead ore. Blaubl-yerz*, Wern. *Mine de plomb bleue*, Broch. The colour of this fpecies is intermediate between dark indigo blue and lead-grey. It occurs maffive, and cryftallized in perfect fix-fided prifms, which are ufually fmall, low, fometimes bulging, with a furface rough and dull. Internally it is feebly glimmering, and its luftre is metallic. The fracture is even, paffing into the fine-grained uneven and flat conchoidal. Its fragments are indeterminately angular. It is opaque, gives a fhining metallic ftreak, is foft, fectile, and eafily frangible. Its fpecific gravity is 5.46. It eafily melts before the blowpipe, burns with a weak blue flame, emits a ftrong fulphureous vapour, and is reduced to pure lead. It is conjectured to be a compound of lead, oxyd of lead, and fulphur; and is fuppofed by Werner to be intermediate between lead-glance and black lead ore. Klaproth difcovered in it phofphoric acid. It occurs in veins, accompanied with black lead ore, white lead ore, malachite, radiated copper azure quartz, fluor-fpar, and heavy fpar. It is not often to be met with, and has hitherto been found only at Zfchoppau in Saxony, at Schemnitz in Hungary, and Brittany in France.

Sp. 3. *Brown lead ore. Braun bleyerz*, Wern. *La mine de plomb brune*, Broch. Its colour is hair-brown, of different degrees of intenfity, fometimes very pale, approaching to grey, and fometimes it paffes into a clove-brown. It occurs maffive, and is cryftallized in fix-fided prifms. The furface of the cryftals is blackifh and rough. Internally it is gliftening, and its luftre is refinous. The fracture is fmall and fine-grained uneven, and fometimes paffes into fplintery. It is foft, not very brittle, but eafily frangible. Its fpecific gravity between 6.60 and 6.98. It melts eafily before the blowpipe, without being reduced; and, during the cooling, fhoots into acicular cryftals. It does not effervefce with acids. According to Klaproth, a fpecimen from Brittany contained,

Oxyd of lead - -	78.58
Phofphoric acid -	19.73
Muriatic acid - -	1.65
	99.96
Lofs	4
	100

It is found at Miefs in Bohemia; alfo in parts of Hungary, Saxony, and Lower Brittany. In Bohemia it is ufually found accompanied with lead-glance, white, black, and green lead ores, copper pyrites, blende, quartz, heavy fpar, &c. It occurs in veins.

Sp. 4. *Black lead ore. Schwarz bleyerz*, Wern. *La mine de plomb-noire*, Broch. The colour of this fpecies is greyifh-black, of different degrees of intenfity. It occurs in mafs, diffeminated or cellular, or cryftallized in fix-fided prifms. It is externally fplendent, and internally only fhining. Fracture fmall-grained uneven, which fometimes paffes into imperfect conchoidal and fplintery. Fragments indeterminately angular; ftreak greyifh white; rather brittle; eafily frangible. Specific gravity about 5.8. Before the blowpipe it decrepitates, and is quickly reduced to a metallic globule. According to Lampadius it confifts of,

Lead - - -	72
Oxygen - - -	7
Carbonic acid - -	18
Carbon - -	2
	99
Lofs	1
	100

It occurs in veins, and is almoft always accompanied with white lead ore and lead-glance, and ufually in the upper part of veins, and in new lead-glance formations. It very frequently encrufts lead-glance, and is covered with white lead ore, and fometimes by green lead ore. It is found in the lead-hills of Scotland; in different parts of Bohemia, Saxony, Salzburg, Lower Brittany, and in Siberia. Previoufly to the analyfis of Lampadius, Haüy fuppofed it was a phofphate of lead; and Werner fufpected that it was a compound of lead, carbonic, and fulphuric acids.

Sp. 5. *White lead ore. Wies-bleyerz*, Wern. *Mine de plomb blanche*, Broch. This is a carbonate of lead: its colour is a greyifh or yellowifh-white, with very many different fhades. It occurs maffive, diffeminated, but moft frequently in a cryftallized ftate. The chief varieties are, 1, the cuneiform octahedron; 2, the pyramidal dodecahedron; 3, the preceding, with a fix-fided prifm interpofed between the pyramids; 4, the fame as variety 3, with fummits of the terminal pyramids replaced by a fix-fided plane; 5, a fix-fided prifm, with fummits compofed of four planes; 6, the fame, with fummits compofed of fix planes. The cryftals are ufually fmall. Externally, it is fpecular fplendent, feldom gliftening: internally, it alternates from highly fplendent to gliftening, and its luftre is adamantine, inclining fometimes to femi-metallic, and fometimes to refinous. The fracture is commonly fmall conchoidal, but it frequently paffes into fine-grained uneven, and even into fine fplintery. Fragments indeterminately angular. It alternates from tranflucent to tranfparent, and is duplicating. It is foft, brittle, and eafily frangible. Its fpecific gravity is from 6 to 7.24, according to the different fpecimens that have been analyfed. Before the blowpipe it flies to pieces, becomes red, yellow, and laftly melts into a globule of metallic lead. It makes a ftrong effervefcence with acids. Its furface becomes black, when expofed to the vapour of fulphuret of ammonia. Its conftituent parts are as follow:

From Siberia, analyfed by Macquer.		From the Lead-hills in Scotland, analyfed by Klaproth.	
Lead - -	67	Lead - -	77
Carbonic acid -	24	Carbonic acid -	16
Oxygen -	6	Oxygen -	5
Water - -	3	Water . -	2
	100		100

But according to two other able chemifts, they are as follow:

From Zellerfeld.	Firft Analyfis.	Second Analyfis
Lead	81.2	80.25
Carbonic acid	16.	16.0
Oxyd of iron	0.3	0.18
Alumine	0.0	0.75
Lime	0.9	0.50
	98 4	97.68
Lofs	1.6	2.22
	100	100

From Ildekanfkoi.	Firft Analyfis.	Second Analyfis.
Lead	74.0	77.50
Carbonid acid	15.0	15.0
Oxyd of iron	0.25	1.25
Alumine	1.0	0.0
Lime	1.0	0.0
Silicia	0.25	0.50
Water	4.0	0.0
	95.50	94.25
Lofs	4.5	5.75
	100	100

It is almoft always accompanied with lead-glance, and occurs in a kind of repofitory. It occurs in veins that traverfe tranfition rocks; though it is found with different minerals, in different parts of the world. It is not a rare mineral, but is feldom found in fufficient quantities to make it worth while to feparate it from the adhering fpar, for the purpofe of fmelting. The fineft fpecimens of this ore that are found in Britain come from the mines of Derbyfhire, the Lead-hills in Scotland, and Minera in Denbighfhire. It is alfo found on many parts of the continent.

Sp. 6. *Green lead-ore. Grün Bleyerz*, Wern. *La mine de plomb verte*, Broch. The colour of this fpecies is grafs-green, which paffes on through the feveral fhades into greenifh-white. The olive and piftachio-green colours are the moft common. It occurs maffive, fometimes reniform, but moft commonly cryftallized. The varieties are, 1. Six-fided prifms, having fometimes the lateral and terminal edges truncated. 2. When the lateral edges of the prifm converge towards their extremities, an acute, double, fix-fided pyramid is formed. The cryftals are fmall; externally fmooth and fhining; internally gliftening; the luftre is refinous. Fracture fmall-grained, uneven. Fragments angular and blunt-edged: it is foft, rather brittle, and eafily frangible. Specific gravity 6.27 to 6.94. Before the blowpipe it does not fly to pieces: it becomes white and melts eafily into a greyifh-globule, but without being reduced even with charcoal. It diffolves in acids without effervefcence. Its conftituent parts are, according to

Fourcroy	
Oxyd of lead	79
Phofphoric acid	18
Oxyd of iron	1
Water	2
	100

Vauquelin	
Lead	45.18
Phofphoric acid	18.17
Oxygen	4.05
Silica	32.
	99.40
Lofs	60
	100

Green lead-ore is, when of a pale colour, apt to be confounded with the preceding fpecies; but it may be diftinguifhed by the following characteriftics: 1. The fracture in this fpecies is fine-grained, uneven, but in white lead-ore it is more or lefs conchoidal. 2. Its luftre is refinous. 3. It is harder than white lead-ore. 4. It is of a greater fpecific gravity. 5. Its cryftals are often aggregated: and 6. Its prifms are generally fhorter than thofe of white lead-ore.

Sp. 7. *Red lead ore. Roth Bleyerz*, Werner. *Red lead-fpar*, Kirwan. *La mine de plomb rouge*, Brochant. The colour of this mineral is of a hyacinth-red, fometimes inclining to aurora, or morning red. It occurs moft commonly cryftallized in broad four-fided prifms, and but rarely maffive, diffeminated, or in membranes. The cryftals are middle-fized: the furface of the cryftals is ufually fmooth, fometimes longitudinally ftreaked. Both externally and internally it is fplendent, and its luftre is intermediate between adamantine and refinous. The fracture is foliated, and the fragments indeterminately angular. It fometimes inclines to tranfparency. It is foft, and in the intermediate ftate between very brittle and fectile: eafily frangible, and its fpecific gravity is fomewhere between 5.6 and 6 0. It melts before the blowpipe into a blackifh fcoria, and may be partly reduced with borax. Specimens have been analyfed by

Vauquelin	
Lead	57.10
Oxygen	6.86
Chromic acid	36.04
	100

Thenard	
Oxyd of lead	64
Chromic acid	36
	100

This mineral occurs in veins in gneifs and mica flate, where it is accompanied with lead-glance, green lead-ore, iron pyrites, brown iron-ftone, native gold and quartz. It is found in Siberia; at Annaberg, in Auftria; and at Upper Faucigny, in Savoy. It is much ufed as a pigment, on account of its beautiful colour, its durability in the atmofphere, and its mixing readily with oil.

Sp. 8. *Yellow lead-ore. Gelbes Bleyerz*, Werner. *Yellow lead-fpar*, Kirwan and Hatchett. *Plomb molybdatè*, Haüy. *La mine de plomb jaune*, Brochant. In this fpecies, which has long been known to mineralogifts, the lead is mineralized by a particular metallic acid, called the molybdic acid. It occurs fometimes maffive, more commonly cryftallized in fmall cryftals; the forms of which are rectangular tables of four fides, or of eight fides, bevelled; the cube, octahedron, equiangular eight-fided table, and double eight-fided pyramid. The tables are ufually broad and thin, and alternate from fmall to very fmall, but are feldom middle-fized.

They are ſometimes united, frequently interſect one another, and form thus the cellular external ſhape. Its colour is wax-yellow, and its luſtre diſtinctly waxy: it is tranſlucent, ſoft, and eaſily frangible. Its ſpecific gravity is rather more than 5. It decrepitates before the blowpipe, then melts into a globule of a grey colour, in which are diſſeminated particles of metallic lead. It gives a blueiſh-white colour to borax: it occaſionally produces a glaſs, which is greeniſh-blue, and ſometimes deep blue. Its conſtituent parts are, according to

Klaproth's Analyſis		Hatchett's Analyſis	
Oxyd of lead -	64.42	Oyxd of lead	58.40
Oxyd of molybdena	34.25	Molybdic acid	38.0
		Oxyd of iron	2.08
	98.67	Silica -	0.28
Loſs	1.33		
			98.76
		Loſs	1.24
			100

Macquart's Analyſis

Lead - -	58.75
Molybdena -	28.0
Oxygen - -	4.76
Carbonate of lime -	4.50
Silica - -	4.
	100.01

It occurs on compact lime-ſtone which is much traverſed by veins of calc-ſpar, and is accompanied with molybdena and yellow lead-earth; ſometimes, alſo, with lead-glance, white, black, and green lead-ore, calamine, blende, the calc and fluor ſpars. It is found principally in Carinthia; though it is met with at Annaberg, in Auſtria; alſo in Hungary, Sileſia, Saxony, Burgundy, in France, and other places.

Sp. 9. *Lead vitriol, or ſulphate of lead. Blei vitriol*, Werner. *Native vitriol of lead*, Kirw. *Plomb ſulphatè*, Haüy. *Le vitriol de plomb natif*, Broch. The colour of this mineral is yellowiſh grey, paſſing to the greyiſh-white; the lighter varieties incline much to white. It occurs only in cryſtals, the form of which is rectangular octahedrons with obtuſe pyramids. The pyramids are often variouſly truncated. Externally it is ſhining; internally it is ſplendent. The fracture is compact; it is more or leſs tranſparent: is ſoftiſh, rather brittle, and its ſpecific gravity is about 6.3. It is eaſily reduced, when expoſed to the flame of the blowpipe; and is inſoluble in the nitrous acid. Specimens have been analyſed by Klaproth; the conſtituent parts are as follow: *viz.* of that from

	Angleſea	Wanlock-head
Oxyd of lead -	71	70.50
Sulphuric acid -	24.8	25.75
Water of cryſtallization	2	2.25
Oxyd of iron -	1	
	98.8	98.50
Loſs	1.2	1.5
		100.

It occurs in lead-glance veins at Wanlock-head, and in brown iron-ſtone in the iſland of Angleſea. It has alſo been found in lead-glance veins in Andaluſia in Spain.

Sp. 10. *Lead-earth. Bleyerde*, Wern. is divided into two ſub-ſpecies; 1, the coherent; and 2, the friable. 1. The coherent, or indurated, named *Verbärtete bleierde* by Werner, and *Le plomb endurci* by Brochant, is of a yellowiſh or greeniſh-grey colour. It is ſometimes of a ſmoky-grey, and ſometimes of a light browniſh-red. It occurs in maſs. Internally it is glimmering, paſſing into gliſtening, and its luſtre is reſinous. Its fracture is fine-grained, uneven, paſſing into fine ſplintery and earthy, alſo into flat conchoidal. It is opaque, or, at moſt, ſlightly tranſlucent on the edges. It gives a browniſh ſtreak, is ſoft, paſſing into friable, not brittle, but inclining to ſectile, and heavy. It is eaſily reduced before the blowpipe, effervеſces with acids, and becomes black with ſulphuret of ammonia. It does not appear to have been hitherto analyſed, but is ſuppoſed to be in intimate combination with white lead ore, alumine, and lime. It occurs with the other ores of lead, and is uſually accompanied by iron pyrites, malachite, and quartz. The yellow varieties are found in Derbyſhire, in ſome parts of Germany, at La Croix in France, and at Nertſchinſk in Siberia. The other varieties are to be met with at Wanlock-head, in the Lead-hills in Scotland, in Saxony, Sileſia, Poland, &c. 2. *Friable lead-earth. Zerreibliche bleierde*, Werner. *Le plomb terreux friable*, Brochant, is of a yellowiſh-grey, approaching to ſulphur-yellow. It occurs friable; ſometimes maſſive and diſſeminated. It is compoſed of dull duſty particles, which are more or leſs cohering, and ſoil a little. It has a rough feel, and is heavy. It occurs on the ſurface, or in the hollows of other minerals, and is uſually accompanied with lead-glance, and other ores of lead, and is found at Wanlock-head, and the Lead-hills of Scotland, at Zellerfeld in the Hartz, near Freyberg, in the electorate of Saxony, in the mountains of Cracow, Poland, at La Croix in France, and at Bereſowſkoi in Siberia. It is in ſome inſtances obſerved paſſing into ſolid lead-earth, and is probably formed by the decompoſition of lead-glance, as it is frequently met with as a cruſt upon it.

Sp. 11. Another ſpecies is denominated a triple ſulphuret of lead. Its colour is dark-grey inclining to black. It occurs cryſtallized. Its primitive figure is a rectangular tetrahedral priſm, beſides which it preſents the following varieties. 1. The primitive cryſtal with ſolid angles replaced by triangular planes. 2. The ſame with lateral edges replaced by rectangular planes. 3. The ſame terminated by a very low and deeply truncated tetrahedral pyramid. 4. Four priſms with deeply truncated dihedral ſummits joined together at their baſes, forming a rectangular croſs. The cryſtals are large and middle-ſized, with a ſplendent metallic luſtre both externally and internally. Its fracture is coarſe-grained and uneven. It is brittle and eaſily frangible. It leaves a faint black trace when rubbed on paper. Specific gravity 5.8 nearly. When ſuddenly heated before the blowpipe it crackles and ſplits; but if gradually heated it melts, and on cooling forms a globule of a dull metallic grey colour. According to an analyſis made by Mr. Hatchett, it conſiſts of

Sulphur - - -	17
Lead - - -	42.62
Antimony - - -	24.23
Copper - - -	12.8
Iron - - -	1.2
	97.85
Loſs - - -	2.15
	100

It is found in a mine at Huel-Boys in Cornwall.

The exiſtence of native lead, which has been maintained by ſeveral mineralogiſts, is extremely doubtful. What has been regarded as a native oxyd of the metal, appears to be rather an earthy carbonate.

Aſſay and Analyſis of Lead Ores.—The moſt common lead ore, galena, is very eaſily analyſed, ſince it is in general compoſed of ſulphur and lead only. Thoſe ores in which the lead is combined with other metals, ſuch as ſilver, copper, antimony, biſmuth, or arſenic, are attended with more difficulty in their analyſis. If the analyſis be made with a view to ſmelt the ore, it will be proper to make the aſſay in the dry, as well as the humid way. The latter will not only give the proportion of lead, but its other conſtituents, by which the ſmelter is directed to uſe the moſt proper fluxes. When, however, the analyſis is made for publication, it ſhould be made by the humid proceſs only, and with the greateſt accuracy.

The common galena may be analyſed by diſſolving 100 grains in dilute nitric acid: the lead will be diſſolved, and the reſiduum will be ſulphur, which may be ſeparated by waſhing. The ſolution of lead may now be treated with ſulphat of ſoda. The lead will be precipitated, with the ſulphuric acid in the ſtate of ſulphat of lead. The precipitate being collected, and dried at the temperature of 212, muſt be weighed, allowing for every 100 grains of the ſulphat 69.85 of lead. The lead may be precipitated from the nitric acid, in the metallic, by means of a plate of zinc. The metallic lead will adhere to the plate, and may be ſcraped off and ſqueezed into lumps, after being waſhed in clean water. The lead obtained by this proceſs is ſuppoſed to contain a ſmall portion of the zinc. It will, therefore, be proper to digeſt the metallic precipitate, for a ſhort time, in very dilute ſulphuric acid, and then waſh the lead with warm diſtilled water.

A ſpecimen of galena containing ſilex was analyſed by Vauquelin.

By ſlowly roaſting a portion of this ore, he found it loſt 12 *per cent.* of ſulphur. Another portion was treated with dilute nitric acid, which diſſolved the lead. The reſiduum was heated to redneſs, by which the ſulphur was volatilized, leaving behind 16.76 of ſulphur. To the ſolution in nitric acid was now added ſulphat of ſoda, when the lead was precipitated in the ſtate of ſulphat. He obtained 63 1 *per cent.* of lead, allowing 100 of ſulphat to contain 75.72 of metallic lead. He then ſaturated the liquor with ammonia, which threw down 3.3 *per cent.* of oxyd of iron, and obtained from the remaining liquor, by carbonat of potaſh, 5 *per cent.* of carbonat of lime.

A ſpecimen of lead ore from Cornwall, conſiſting of lead, ſulphur, antimony, and copper, was analyſed by Mr. Hatchet.

To 200 grains of the ore, in a matraſs, he added 2 oz. of muriatic acid. While the mixture was heated, he added, from time to time, ſmall quantities of nitric acid, juſt to keep up an efferveſcence, till the metals were oxydated and diſſolved. After being gently heated for an hour, the ſolution was complete, and of a green colour, owing to the preſence of the copper. The ſulphur was ſeparated and floated on the liquid, which being collected was digeſted in muriatic acid. When dried it weighed 34 grains.

The above ſolution, and the muriatic acid in which the ſulphur was digeſted, were mixed together, and diluted with ſix pints of diſtilled water. The mixture became turbid and milky, and on being filtered while hot, the pure oxyd of antimony was left on the filter, which being waſhed with more boiling water, was dried, and found to weigh 63 grains.

When the liquid, which had paſſed through the filter, including the waſhings, was cold, ſome muriat of lead was depoſited in cryſtals, owing to the ſparing ſolubility of that ſalt. The whole was evaporated to a ſmall quantity of liquid, ſufficient to hold the copper in ſolution. This liquid, being ſeparated from the ſolid muriat of lead, contained a ſmall portion of that ſalt. A few drops of ſulphuric acid being added, however, ſeparated it in the ſtate of ſulphat of lead. The maſs of muriat of lead left by evaporation, was now re-diſſolved in boiling water, and decompoſed by ſulphat of ſoda. The ſulphat of lead here formed was added to that produced from the ſeparated liquid, which, on being waſhed and dried on a ſand bath, weighed 120.2 grains. The green liquid containing the remainder of the mineral was now ſaturated with ammonia and an exceſs added, which rediſſolved the oxyd of copper, forming a vivid blue ſolution. A quantity of oxyd of iron now ſubſided, which, when ſeparated, weighed 2 4 grains.

The ſolution of copper was now evaporated nearly to dryneſs, and boiled with pure potaſh, when the black oxyd of copper was left at the bottom of the veſſel, which being waſhed, ſeparated, and dried, weighed 32 grains.

In this analyſis the ſulphur is the only ſubſtance ſeparated in a ſtate of purity. The 63 grains of oxyd of antimony, allowing it to contain 23.08 *per cent.* of oxygen, would afford 48.46 of antimony. The 120.2 grains of ſulphat of lead, allowing 70.9 to the 100, will give 85.22 of metallic lead. The 32 grains of oxyd of copper, reckoning the black oxyd of that metal to contain 25 in the 100, will yield 24 grains. If we reckon the 2.4 grains of iron at 1.2 of metal, the analyſis will ſtand as follows, when reduced to 100.

Sulphur - - -	17
Antimony - - -	24.46
Lead - - -	42.61
Copper - - -	12
Iron - - - -	1.2
	97 27
Loſs - - -	2.73
	100

If ſilver had been a conſtituent of the ore, the above proceſs would have been a little varied. In the firſt operation the ore would have been diſſolved in dilute nitric acid, the antimony would have been in part diſſolved, and left at the bottom of the veſſel in the ſtate of white oxyd. When the ſulphur and the antimony, by dilution with water, are ſeparated, muriatic acid muſt be added. The lead will be in part, and the ſilver entirely precipitated. The muriat of lead may be ſeparated, by boiling water, from the muriat of ſilver. The weight of ſilver may be rated at 77.52 in the 100 of muriat. The other metals may be ſeparated as in the laſt proceſs. Arſeniated lead ore requires a ſtill different treatment. It was analyſed by Vauquelin as follows: 100 parts of ore were roaſted for half an hour, occaſionally adding a little tallow, which ſerved to reduce the arſenic and facilitate its eſcape. By this treatment it loſt 38 parts, which was preſumed to be oxyd of arſenic; the remaining maſs was boiled with ſtrong muriatic acid for an hour. A quantity of oxymuriatic acid eſcaped, the liquid aſſumed a red colour, and white needle-formed cryſtals of muriat of lead were depoſited. The lead by this means was converted into a muriat, which being diſſolved in boiling water, and treated with ſulphat of ſoda, affords ſulphat of lead. This precipitate, being ſeparated and dried, weighed 25 parts, which gave 20.2. of lead, allowing 80.8 to the 100 of ſulphat. The liquid thus freed from lead being treated with pure ammonia, afforded a precipitate equal to 39 grains, conſiſting of oxyds of iron and arſenic. The circumſtance of oxymuriatic acid being given out, when the oxyd of lead was di-

gested with muriatic, induced Vauquelin to conclude that it was in a state of peroxyd.

In this account the last part of the process appears incomplete, in the circumstance of the oxyds of arsenic and iron being mixed together. The former of these may be separated, boiling the two in nitromuriatic acid, which will convert the oxyd of arsenic into arsenic acid, and which may be separated by washing.

Carbonat of lead was analysed by Klaproth by the following process. He introduced 100 grains of this ore into 200 grains of nitric acid, and diluted it with 300 of water. The carbonic acid escaped in the form of gas, making a loss of weight equal to 16 grains. Into this solution was suspended a cylinder of zinc. In 24 hours the lead was precipitated in the metallic state, which weighed 77 grains, equal to 82 of oxyd.

Sulphat of lead has been analysed by the same chemist: 100 grains of the ore were first roasted at a red heat, and lost two grains, supposed to be water. The remainder was then heated to redness in a platina crucible, with 400 grains of carbonat of potash. By this treatment a yellow reddish mass was obtained, which, on being digested in water and filtered, afforded 72 grains of oxyd of lead. This was next dissolved in nitric acid, leaving a residuum of one grain of oxyd of iron. A cylinder of zinc was introduced into the solution, which precipitated the lead in the metallic form, in quantity equal to 66½ grains.

The alkaline matter which passed through the filter contained the sulphuric acid of the sulphat of lead, with excess of alkali; this excess was saturated with nitric acid, and the liquid acetat of barytes was added, which caused a precipitation of 73 grains of sulphat of barytes: this he allows to contain 25 grains of real sulphuric acid. Hence the result is

Oxyd of lead	72
Sulphuric acid	25
Oxyd of iron	1
Loss by roasting	2
	100

We have also the analysis of phosphat of lead by the same ingenious experimenter.

One hundred grains of this native salt were dissolved in dilute nitric acid; into this solution nitrat of silver was dropped till it ceased to precipitate: the insoluble substance, which was muriat of silver, weighed 11 grains, indicating 1.7 grains of muriatic acid. Sulphuric acid was now added to precipitate the lead. The sulphat of lead weighed 106 grains, which contained 78.4 of oxyd of lead. The excess of sulphuric acid was separated by adding nitrat of barytes, and then nearly neutralized with ammonia. On adding acetat of lead, 82 grains of phosphat of lead were precipitated, containing 18.37 of phosphoric acid: muriatic acid was now added to the solution, and evaporated to dryness. The dry mass was digested with alcohol, which dissolved the muriat of iron, the presence of which was detected by prussiat of potash, and was found equal to $\frac{1}{10}$th of a grain of the oxyd.

Molybdat of lead was analysed by Mr. Hatchett. He boiled a quantity of the ore in sulphuric acid, till it would dissolve no more. This formed sulphat of lead, while the molybdic acid was dissolved in the sulphuric acid. The sulphat of lead was boiled with carbonat of soda, and was afterwards washed: this appeared to be carbonat of lead. The nitric acid dissolved all but a small quantity, which was found to be silex. The lead was next precipitated by sulphuric acid. The solution of the molybdic acid in the sulphuric acid was diluted with 16 parts of water, and saturated with ammonia; when a little oxyd of iron was precipitated. The solution was now evaporated to dryness, and a strong heat given to sublime the sulphat of ammonia. The remaining mass, when boiled with nitric acid to dryness, afforded molybdic acid of a yellow colour.

Although the analysis of the different ores may have pointed out general methods for the separation of lead from other metals, some hints may, nevertheless, be necessary for the analysis of the alloys of lead. Lead is most frequently alloyed with tin, silver, antimony, or bismuth. The alloy of tin and lead may be dissolved in dilute nitric acid. The lead will be entirely taken up. Most of the tin will be precipitated in the state of white oxyd, by the addition of water. If sulphuric acid be now dropped into the solution till the precipitation ceases, the lead, in a state of sulphat, will be obtained, while the remaining tin will be dissolved, which may afterwards be precipitated by an alkali. Lead may be separated from silver, when both those bodies are dissolved in pure nitric acid. The silver may be precipitated in the state of muriat, by adding muriat of soda. The lead may be afterwards precipitated by sulphuric acid.

To separate lead from bismuth, dissolve the alloy in nitric acid, then add a large quantity of water, which will precipitate the greatest part of the bismuth in the state of white oxyd. The lead must then be precipitated by sulphat of soda, and the remainder of the bismuth by potash.

The separation of lead from antimony may be performed by the same process used for separating tin.

It may be here noticed, that in all cases where sulphur is present in the ore or substance to be analysed, if the nitric acid be employed, it must be very dilute, otherwise the sulphur will combine with its oxygen, forming sulphuric acid. In order to know when this takes place, the solution must be tested with nitrat of barytes. If, however, lead be present, it will combine with the sulphuric acid as it is formed, and fall to the bottom of the vessel.

Reduction of the Ores, or smelting of Lead.—Two processes are employed for the smelting of lead, the one by means of a blast furnace, called an ore-hearth, and the other by means of a reverberatory furnace. The latter is used throughout Derbyshire and North Wales, and is undoubtedly the best, where coal is not very scarce. In the former of these methods the ore and the fuel are mixed together, and exposed to the blast. The heat dissipates the sulphuret, the ore being the common sulphuret of lead or galena. A portion of the lead is oxydated, which facilitates the vitrification of the earthy parts of the ore, and of the fuel. These together constitute the slag or scoria. The metallic lead falls into the lower part of the hearth, and is defended from the oxygen of the blast by the scoria, which is fluid upon its surface. The liquid lead is let off from time to time, always retaining a portion for the scoriæ to float upon. When the whole of the lead is to be drawn off, the blast must be stopped, and some lime thrown upon the liquid scoria, which renders it concrete, while the lead, being still liquid, can be run off.

The reverberatory furnace employed for smelting lead is made on the same plan with those commonly used for puddling iron, differing in size, and a few other particulars. The fire is made at one end, and the flame plays over the hearth, entering an oblique chimney at the end, which terminates in a perpendicular one, of considerable height. The length of the hearth, from the place where the fire enters, to the chimney, is 11 feet; two feet of this length next the fire constitutes the throat of the furnace; the width of the same is four feet, and its depth about six inches; the

length of the fire-place is four feet, equal to the width of the throat; its width two feet, and depth three feet, from the grate up to the throat of the furnace. The reft of the hearth is a concave furface, nine feet long, four and a half feet wide at the throat of the furnace, feven feet four inches wide at the diftance of two feet from the throat, feven feet two inches in the middle of the hearth, five feet eleven inches at two feet diftance from the chimney, and two feet ten where the flame enters the chimney at two apertures, each ten inches fquare. Thefe apertures terminate in the oblique part of the chimney, the fection of which is 16 inches fquare, which communicates with the main chimney, the fection of which is twenty inches fquare, fuppofing a ftraight horizontal line, drawn from the lower plane of the throat of the chimney to the oppofite fide of the furnace; the loweft part of the concave hearth, which is in the middle of this cavity, is nineteen inches below this line, the roof of the furnace being feventeen inches above the fame line: the reft of the hearth is conformably concave.

On each fide of the furnace are three openings, each about ten inches fquare, provided with iron doors, to be removed as occafion may require. They are arranged at equal diftances from each other, between the commencement of the hollow hearth and the entrance into the chimney. The lower part of thefe apertures is on a level with the horizontal line above alluded to, being for the purpofe of ftirring and raking the ore, &c. Befides the larger openings there are two fmall apertures, one below the large middle opening, and nearly on a level with the bottom of the furnace; the other under that next to the chimney, at fome diftance above the firft aperture. The firft is a tap-hole for the lead, and the fecond for the fcoria. The ore is introduced by a veffel in the fhape of a hopper, placed in the roof of the furnace.

Previous to the ore being fmelted, it requires to be feparated as much as poffible from the earthy matter in which it is imbedded. Although galena, which is the ore ufed for fmelting, is moft frequently accompanied by fulphat of barytes, fluats and carbonat of lime, it is found to exift in cryftallized diftinct maffes, and can be feparated from it by mechanical means to a tolerable extent. The whole of the ore, with the earthy matter, is pounded to a certain degree with hammers, and is chiefly performed by women. In fome places, however, it is broken down by paffing it through iron rollers preffed together by great weights. After the ore has been thus reduced, the earthy matter is feparated by wafhing. The powder to be wafhed is introduced into a fieve or riddle, and placed in a large tub full of water. By a certain motion given to the riddle, the lighter or earthy parts are thrown over the edge of the fame, while the galena, by its greater fpecific gravity, is retained. This procefs requires great dexterity, which can be acquired by experience only. There are, however, fome impurities which cannot be feparated by this mechanical procefs, and are generally fmelted with the ore. Thefe are *blind*, or *black-jack*, called by the fmelter *mock* ore; pyrites, or fulphuret of iron, named *Brazil* by the workmen. When the ore abounds much with thefe fubftances, the procefs of fmelting is more difficult, and requires an extra affiftance of flux to reduce it.

In the ftate above defcribed, the ore is introduced at the hopper in the middle of the roof of the furnace, and fpread upon the concave hearth, to expofe it as much to the flame as poffible, in order to facilitate the efcape of the fulphur. This fhould be performed by a long continued heat which is not violent, in order that the fulphuret itfelf may not be volatilized, an effect which, more or lefs, always takes place. The moment the fulphur has left the lead it begins to combine with oxygen. The oxyd of lead, thus formed, combines with the earthy matter, which it renders fo fufible as to become liquid upon the fulphur of the melted lead, and defends it from the future action of the oxygen. At this ftage of the procefs the fire is raifed to feparate as quickly as poffible the melted lead from the liquid fcoria. The latter is now let off at the upper tap hole, leaving a fmall portion ftill upon the lead to preferve it from the air. The fire at this period is lowered, and a quantity of coal-flack thrown in upon the melted mafs. This ferves as well to facilitate the cooling, and to caufe the reduction of fome oxyd of lead, which alfo tends to ftiffen the melted fcoria. This laft effect, however, is not produced fufficiently, till a quantity of powdered lime is thrown into the furnace. By this treatment the remaining fcoria becomes concrete, and is then broken to pieces and pufhed to the oppofite fide by means of a rake, and taken out of the furnace at the different openings on the fame fide. The liquid lead is now let out, at its proper aperture, into a large iron pan, or ciftern, from whence it is laded into moulds to caft into pigs. The furnace is now ready to be charged again. When the ore abounds with much impurity, the oxyd of lead is not fufficient to give the proper degree of liquidity to the fcoria. In this cafe a certain quantity of fluat of lime is added, which has the property of forming a very fufible compound with fulphat of barytes, an ingredient very common in the ore.

This flux has been ufed from time immemorial for the fame purpofe, and has no doubt derived its name from its properties as a flux. See *Fluat of* LIME.

The concrete fcoria, which is taken out of the furnace, is found to contain fome lead, independent of that in the ftate of oxyd, and chemically combined. This is generally lodged in the cavities of the fpongy mafs. Thefe maffes are taken to a kind of blaft furnace, called a flag-hearth. By this fecond fufion of the fcoria, the lead drops through the liquid mafs into the lower part of the hearth, where it is not acted upon by the blaft, and from thence is let off and caft into pigs. This lead is faid to be of an inferior quality. Some ores of lead contain filver. The great affinity of lead for that metal is fuch, that the whole of it is found in the lead (fee SILVER), from whence it is afterwards feparated.

Phyfical and chemical Properties of Lead.—Lead is of a bluifh-white colour, when made as bright as poffible. This is beft effected by fcraping and burnifhing. This polifh it foon lofes by expofure to air.

Its foftnefs is fuch, that a cylinder of one inch in diameter and twelve inches long, may be eafily bent by a perfon of ordinary ftrength: indeed, it is the moft foft and flexible of the metals. Its fpecific gravity, according to Briffon, is 11.3523, and fo far from being increafed by the hammer, agreeably to that change in other metals by the fame effect, Mufchenbroeck afferts that it is diminifhed. It may be here proper to obferve, that thofe metals which are fufceptible of the moft perfect cryftallization, will undergo the greateft condenfation by the hammer, provided the metal be fufficiently malleable. Hence we find this property the moft confpicuous in brafs, and in bliftered fteel. See METAL.

Lead, in common with its foftnefs, is the leaft elaftic of the metals; to which alfo may be attributed its little tenacity. Its hardnefs is increafed by hammering, and its tenacity in a proportionate degree.

Lead is exceedingly malleable, which connected with its exceffive foftnefs, admits of its being rolled into thin fheets with little power. Its tenacity, according to Dr.

Thomſon, is ſuch, that a wire of $\frac{1}{12.6}$ of an inch will ſupport only 18.4 pounds. Lead fuſes at about 600° of Fahrenheit, and if raiſed to a much higher temperature, will be found to diminiſh by evaporation. If lead be melted and poured into an iron mould, it will be found to concrete on the ſides next the mould, while the middle part will be liquid for a ſhort time. If this liquid part be poured off, or let out at a plug-hole at the bottom, the interior ſurface of the ſolid part will exhibit a cryſtalline form. The cryſtals will be larger and more diſtinct as the cooling is ſlower.

Lead is much employed in the arts, particularly for buildings and ciſterns. For the former of theſe purpoſes it has many advantages. It is eaſily worked into any ſhape on account of its great ſoftneſs, and is ſufficiently malleable to fold two edges over each other, ſo as make it water-tight without ſoldering. This is a very great advantage, ſince, when the pieces are ſoldered together, the expanſion and contraction, by a change of temperature, ſoon breaks it to pieces.

Although it is at preſent in general uſe for water-ciſterns, pumps, and pipes for conveying water, ſerious objections have been made to it by different philoſophers, particularly Dr. Lambe, ſo far as regards its effects on the human economy.

A very ingenious paper was ſome time ago publiſhed by Morveau, in which he ſhews that the water expoſed to the leaden veſſels would frequently be pernicious, if ſome ſulphuric acid were not preſent, which never fails to precipitate lead from any of its ſolutions. Thus we ſee that lead is the leaſt objectionable for mineral waters containing the ſulphuric acid, which is very general in almoſt all ſprings.

Great miſchief has been produced by the uſe of lead in dairies; although we lament to ſay that this practice is ſtill followed up to a certain extent. If the milk runs into the ſlighteſt acidity, we muſt expect ſome lead to be diſſolved, and its probable conſequences if taken into the ſtomach.

The diſeaſe called the Devonſhire colic, was proved by ſir George Baker, in ſeveral excellent papers written by him, and publiſhed in the Philoſophical Tranſactions of that time, to be occaſioned by lead diſſolved in the cyder, and which had been furniſhed from the cyder preſſes, which were lined with that metal; but was in conſequence of this valuable diſcovery laid aſide.

We have heard of a ſimilar diſeaſe in the Weſt Indies, acquired by drinking new rum. The rum was found to contain lead, which had been taken from the leaden worm uſed for the condenſation of the ſpirituous vapour. What, however, is very ſingular, the rum loſt its deleterious property by keeping about twelve months. This fact was not explained at the time, but it has lately been cleared up by a ſeries of experiments made by the writer of this article. The new rum is generally put into oak caſks, from whence the liqour extracts a quantity of tan and gallic acid. Theſe ſubſtances combine with the lead in ſolution, forming a perfectly inſoluble ſubſtance, which falls to the bottom of the caſk. Theſe facts ſhew that lead ſhould not be uſed in any ſituation where fermented liquors are preſent, ſince in every ſtage of their exiſtence, they contain more or leſs acetic acid. And it muſt not be forgotten, that all diſtilled ſpirits will contain the ſame acid, from the circumſtance of its being volatile and coming over with the ſpirit.

We have, however, abundant ſatisfaction in knowing that the exiſtence of lead and gallic acid in ſpirits, wines, or other fermented liquors, are incompatible: and that all liquors which have been kept in oak caſks for a certain time muſt be freed from lead. If we find the preſence of gallic acid by a ſolution of iron, we may pronounce ſuch liquid free from lead.

Theſe obſervations, which may appear out of place, are given with a view to guide thoſe who may be making or uſing veſſels of lead, which, under ſome circumſtances, are attended with deplorable conſequences.

Alloys of Lead formed with other Metals.—One part of tin and two of lead form an alloy, fuſible at about 350° of Fahrenheit, and uſed by tinmen and others under the name of ſoft ſolder. See SOLDER.

Lead forms an imperfect alloy with copper. The metal uſed for common braſs-cocks is an alloy of theſe two metals The lead is ſo imperfectly combined with the copper, that when a piece of the metal is expoſed to a certain heat, the lead ſeparates from the copper in bright globules of the former.

The alloy of antimony with lead is not uncommon. Sixteen of lead and one of antimony form the printers' type metal.

Lead eaſily combines with mercury, forming an amalgam. This is effected either by putting mercury into melted lead, or by putting lead, in ſmall particles, to the mercury. See AMALGAM.

An alloy of ſilver and lead is eaſily formed. Indeed lead is frequently uſed to take ſilver from plated iron, which is afterwards got from the lead by cupellation.

We are indebted to Mr. Hatchett for ſome valuable facts relative to the alloys of lead and gold. One part of lead to eleven of gold forms a very brittle alloy, having a fracture of a pale brown colour, deſtitute of metallic luſtre.

The alloys in any proportion have the ſingular property of being of leſs ſpecific gravity than the mean, the very contrary of which is obſerved in moſt other compounds of metals. The following is a table given by Mr. Hatchett exhibiting theſe facts.

Metals.	Grains.	Specific Gravity of Alloy.	Bulk before Union.	Bulk after Union.	Expanſion.
Gold Lead	442 38	18.08	1000	1005	5
Gold Copper Lead	442 19 19	17.765	1000	1006	6
Gold Copper Lead	442 30 8	17.312	1000	1022	22
Gold Copper Lead	442 34 4	17.032	1000	1035	35
Gold Copper Lead	442 37.5 .5	16.627	1000	1057	57
Gold Copper Lead	442 37.75 .25	17.039	1000	1031	31

When lead is expofed to the air for a little time, it foon appears of different colours, not unlike the prifmatic colours. By a longer expofure, affifted with moifture, it becomes covered with a white powder. This is the oxyd of lead combined with carbonic acid. This change is facilitated by heat, and ftill more by the fumes of acetic acid or vinegar. It is by this means that the white lead of commerce is made, of which we fhall treat hereafter.

If melted lead be expofed to the oxygen of the atmofphere, a greyifh-yellow powder begins to form upon the furface. By keeping it expofed for fome time, the powder becomes more yellow. In this ftate it is called *mafficot*, or yellow oxyd of lead. It contains about 6.88 of oxygen.

This oxyd is made, in the large way, in a furnace not unlike a baker's oven. The middle of the hearth contains a recefs for expofing the melted lead. On each fide, and a little below the level of the hearth, is a fire, the flame of which paffes flowly over the hearth, giving fufficient heat to keep the lead melted, and paffes up a chimney near the mouth of the furnace. As foon as the lead is melted, a perfon is conftantly employed to agitate it, in order to expofe greater furface to the air. This manual operation is performed by a rake fufpended from a chain, fo that the perpendicular part of the rake dafhes through a portion of the melted lead, by merely moving it backwards and forwards. By the fame motion, the oxyd which is formed is pufhed away from the furface of the lead, leaving it free to the action of frefh oxygen. This procefs being kept up, the lead is at length converted into a greenifh-yellow powder, mixed with lumps of metallic lead. This powder is ground in a mill and then wafhed, by which means the metallic lead is feparated, and the powder becomes of a more bright yellow. The green colour was therefore owing to a mixture of the blue particles of lead, mixed with the yellow oxyd. The yellow oxyd here produced is called *mafficot;* which fee.

This oxyd appears capable of combining with more oxygen by a fecond expofure. For this purpofe the yellow powder, after being wafhed and dried, is returned into the furnace above-mentioned, or one of fimilar conftruction, kept for this fecond procefs only. The heat is kept uniform but not great, and the oxyd raked about to expofe as much furface as poffible. It gradually changes colour, and ultimately affumes a fplendid red. In this ftate it is called *minium;* which fee. Although during this procefs the oxyd appears gradually to pafs through all the fhades of orange colour from yellow to red, the two latter can only be confidered as diftinct oxyds, the intermediate tints being mixtures of the two.

If we confider the yellow as the firft or protoxyd, the red will be the fecond, and the brown, yet to be treated of, the third and the peroxyd. Prouft, however, has given fome reafon to believe that the yellow is not the firft. The oxyd which is precipitated from the nitric acid when heated to rednefs, to drive off the water and carbonic acid, is found to be the yellow oxyd in a very perfect ftate. The author above-mentioned informs us, that if cryftals of the common nitrat of lead be boiled with fome pieces of metallic lead, fcaly yellow cryftals are formed. This falt, decompofed by potafh, affords an oxyd which Prouft fuppofes to contain lefs oxygen than the yellow. Dr. Thomfon repeated his experiment; he found the oxyd not to differ in appearance from the yellow, and makes it to confift of lead, 91.5 lead, and 8.5 oxygen. This appears to be rather lefs oxygen than, according to his own analyfis, is contained in the yellow. But there is reafon to believe, that in Dr. Thomfon's analyfis of the yellow oxyd, the oxygen is rated too high. The fame oxyd, according to Bucholz, is compofed of 100 lead and eight of oxygen, equal to 7.4 *per cent.* This analyfis appears to have been made under fuch circumftances as to entitle it to much credit. From the average of three analyfes of the yellow oxyd, obtained from acetat of lead, the writer of this article made the oxygen 7.4 *per cent.* Hence we have abundant reafon to doubt the exiftence of an oxyd below the yellow oxyd, fince it appears, from Dr. Thomfon's own account, that the oxyd, faid to confift of lefs oxygen than the yellow, contains 8.5 *per cent.*, being 1.1 more than Bucholz makes the yellow oxyd.

If nitric acid in fufficient quantity be added to the red oxyd of lead, nearly the whole will be diffolved; $\frac{1}{13}$th of the oxyd will remain at the bottom of the veffel, which, when collected and dried, is of a dark brown colour, and is called the brown oxyd of lead. The following procefs is given by Vauquelin: Mix a quantity of the red oxyd of lead with water in a Woulff's apparatus, and let the oxymuriatic acid gas pafs through the mixture. The oxyd gradually becomes of a deeper colour, and is at laft diffolved. From this folution the brown oxyd is precipitated by potafh. From every 100 parts of the red oxyd 68 of the brown may be obtained.

This oxyd is of a flea-brown colour, having no fmell or tafte. It is infoluble in any of the acids. It converts the muriatic into oxymuriatic acid, by giving up a portion of its oxygen. When rubbed brifkly in a mortar with powdered fulphur, the fulphur inflames, producing a ftrong fmell of fulphurous acid. According to the analyfis of Prouft, this oxyd is compofed of 79 lead and 21 oxygen. Dr. Thomfon makes it 81.6 lead and 18.4 oxygen.

It appears highly probable that we have only three oxyds of lead, namely, the yellow, the red, and the brown. The firft, according to Prouft, contains 9 *per cent.*; Thomfon, 10.3; Bucholz, 7.4; the writer of this article, 7.4: the average of all thefe being 8.5. The red oxyd, by Dr. Thomfon's analyfis, contains 12 *per cent.*: the brown, according to Prouft, contains in the 100, 21 oxygen; Dr. Thomfon makes 18.4: the mean of thefe is 19.7.

Agreeable to the average refults of thefe different analyfes, we cannot help being forcibly ftruck with the beauty of Mr. Dalton's hypothefis relative to the limited proportions with which bodies combine. He makes the atom of lead to weigh 95, or to be 95 times heavier than an atom of hydrogen; the atom of oxygen being 7 times heavier. In referring to the doctrine advanced by this ingenious chemift, it will be feen that he holds the neceffity of bodies combining atom to atom, or in fome multiple of the fame; as, 2 to 1, 3 to 1, &c. The firft oxyd of lead, agreeably to the above data, muft be 1 to 1, or 95 to 7; the fecond oxyd, 95 to 14; and the third, 95 to 21. Hence thefe proportions reduced to 100, will ftand as follows: $\frac{95+7}{7} = \frac{100}{6.86}$, or 6.86 in the 100, for the firft oxyd. Then, for the fecond, $\frac{95+14}{14} = \frac{100}{12.84}$, or 12.84 in the 100. Laftly, for the third or peroxyd, $\frac{95+21}{21} = \frac{100}{18.1}$, or 18.1 in the 100. The proportions by analyfis give, for the firft, 8.5; fecond, 12; and the third, 19.7: by theory, 6.86, 12.84, and 18.1.

The fecond and third oxyds of lead give out oxygen, by expofure to heat in a crucible, and are reduced to the ftate of the firft oxyd. If the heat be raifed a little above red-

nefs, the yellow oxyd fufes into a glafs, in which ftate it is called the vitreous oxyd of lead. It becomes fo exceedingly fluid, as to run through the common crucibles. In this ftate it has the power of oxydating, and combining with the oxyds of all the metals which are oxydatic, by expofure to air with heat: and hence is employed to great advantage in the cupellation of the nobler metals. See SILVER.

When lead is oxydated at a high temperature, fuch as that employed in the feparation of filver from lead, the yellow oxyd fufes as it is formed, and is blown from the furface of the lead by bellows. In this ftate it is called *litharge;* which fee. It confifts of the yellow oxyd, united to a portion of carbonic acid. For this part we are indebted to Dr. Thomfon.

Lead combines with fulphur and phofphorus.

Sulphuret of lead may be formed by projecting fulphur into melted lead, or by ftratifying thin plates of the metal with the fulphur. The compound is very brittle, of a dark grey colour. It may be cryftallized by flow cooling; under which form it exhibits a brilliant fracture, refembling the native fulphuret, or *galena.* This fulphuret, according to Dr. Thomfon, confifts of 86 lead and 14 fulphur. According to Dalton's hypothefis, it confifts of one atom of lead to one of fulphur: the former atom being 95, and the latter 13, will give $\frac{95 + 13}{13} = \frac{100}{12}$, or 12 to 100; which agrees with feveral other analyfes very nearly.

Lead appears capable of combining with a fecond dofe of fulphur, conftituting a compound, which is more brilliant, and of a lighter colour. It may be eafily diftinguifhed from the common kind, by its burning in the flame of a candle.

It is called the *fuper-fulphuret of lead,* and, according to Dalton's hypothefis, muft confift of one atom of lead and two atoms of fulphur, which would give $\frac{95 + 2 \times 13}{26} = \frac{100}{21.5}$, or 21.5 *per cent.* Dr. Thomfon makes it 25 *per cent.* It is to this chemift we are indebted for our knowledge of this fubftance.

Phofphuret of lead may be formed by mixing together equal parts of filings of lead and phofphoric glafs; the mixture being fufed in a crucible. It is of a filvery blueifh-white colour. It poffeffes flight malleability, and may be cut with a knife. It is compofed of 88 lead and 12 of phofphorus. Dalton makes the atom of phofphorus to weigh 9: hence this compound of 1 to 1 will give $\frac{95 + 9}{9} = \frac{100}{8.6}$.

Salts of Lead.—Moft of the acids combine with the yellow oxyd of lead, forming peculiar compounds. By far the greateft proportion of thefe compounds is infoluble in water. All thofe which are foluble have a fweetifh tafte, attended with a roughnefs which it leaves on the tongue, fimilar to that of red port, and fome other wines. This property has caufed it to be ufed for the villainous purpofe of mixing with four wine, which does not only take up the acid, but adds a roughnefs and fweet vinous flavour, exceeding impofing upon the palate. Some have fufpended bags of fhot in the cafks of wine; others have added common white lead.

Mankind are now fo well acquainted with the different tefts for lead, that it is very feldom found in thofe liquors. Water impregnated with fulphuretted hydrogen gas will inftantly turn wine muddy and black, which contains lead. If a folution of iron be dropped into wine, and it turns black, the prefence of gallic is indicated: and from what we before obferved, the exiftence of lead and that acid are incompatible in the fame liquid.

Sulphat of Lead.—Lead is fcarcely acted upon by the fulphuric acid, in the cold. If the acid be boiled with the lead, fumes of fulphurous acid will be given out, and a portion of the lead oxydated, which combines with the acid, forming a whitifh pafty compound. If the acid be in excefs, and the mafs wafhed in water, the fubftance becomes divided into two portions, namely, the fulphat of lead, which is infoluble, and the fuperfulphat, which is flightly foluble, and will be depofited in cryftals.

It is from the circumftance of the infolubility of the fulphat of lead, that the metal can be ufed with fuch advantage for the lead houfes, ufed in making fulphuric acid, and for making veffels which have to hold this acid. The fulphat which firft forms upon the furface defends the lead not only from the action of this acid, but from any other folvent of this pernicious metal. Sulphat of lead may be beft formed by adding fulphat of foda to the acetat of nitrat of lead. A denfe white precipitate is formed, which is fulphat of lead. This falt is produced in great abundance by the calico-printers, in making acetat alumine, with alum and acetat of lead. It forms an excellent paint with oil, for ftanding the action of acids.

Kirwan gives the proportion of this falt at 23.37 acid, 75 acid yellow oxyd, 1.63 water in the 100; Bucholz, 24.72 acid, 75.28 oxyd; and Klaproth, 26.5 acid, and 73.5 oxyd: the mean of thefe is 24.86 acid, and 75.14 bafe. Calculated by Dalton's theory, the atom of fulphuric acid weighs 34: therefore, $\frac{95 + 7 + 34}{34} = \frac{100}{25}$; or, the acid is 25 in the 100: then, $100 - 25 = 75$ the bafe.

Sulphite of Lead.—The fulphurous acid has no action upon lead: but it combines with the yellow oxyd, forming an infoluble compound, having no remarkable properties. When expofed to a red heat, the acid is difengaged, in the form of gas.

When the fulphurous acid is added to the red oxyd of lead, the acid takes oxygen from the oxyd, reducing it to the ftate of yellow oxyd. The acid is converted into the fulphuric, and combines with the oxyd, forming the fulphat of lead.

Dr. Thomfon gives the proportions at

74.5 oxyd,
25.5 acid.

100

Nitrat of Lead.—When the nitric acid is a little diluted, it acts with confiderable rapidity upon lead. If it be a little affifted by heat, the whole will become fpeedily diffolved, forming nitrat of lead. This confifts of the yellow oxyd of the metal united to a portion of the acid. If the folution be evaporated, it affords cryftals of tin, in fix-fided pyramids of a filvery white colour. This falt diffolves in 7½ of boiling water. When the cryftals are heated, they undergo a flight detonation: the fame takes place when they are rubbed with fulphur in a hot mortar.

According to experiments of Dr. Thomson, this salt consists of,

66 oxyd,
34 acid.

When the crystals of the last salt are boiled with metallic lead, yellow scaly crystals are formed, constituting, according to Dr. Thomson, a subnitrat, consisting of

81.5 oxyd,
18.5 acid,

100

By Dalton's theory the weight of an atom of nitric acid is 19: in most of the nitrats he supposes one atom of the base to unite with two atoms of acid. The nitrat of lead, already described, should, according to the above analysis, consist of at least two atoms of acid to one of base, for $\frac{102 + 2 \times 19}{38} = \frac{100}{27.14} = 27.14$ of acid, and 72.86 of base.

The acid here falls considerably short of that in the analysis of Dr. Thomson. The latter salt, which we have called the subnitrat, should have one atom less of acid. Hence $\frac{95 + 7 + 19}{19} = \frac{100}{15.7}$, which gives 15.7 acid, and 84.3 of oxyd = 100.

Muriat of Lead.—Muriatic acid has a very feeble action on lead, but it readily dissolves the yellow oxyd, forming the muriat of lead. This salt may be also formed by adding muriat of soda to nitrat of lead. The precipitate which is formed is the salt in question. It dissolves in 22 parts of cold water. This is the fact only when no excess of this acid, or when no other acid is present; since the salt is soluble in most acids to a greater extent than in water. When this salt is mixed with the sulphat of lead, it may be separated from it by its solubility in the acetic acid. Muriat of lead is much more soluble in hot than in cold water. Hence, when a saturated hot solution is suffered to cool, the salt is deposited in crystals of a silvery-white colour. When heated they readily melt, and on cooling assume a slight transparency, from which it has been called *Plumbum corneum.*

On the application of greater heat some of the salt evaporates in a white smoke, leaving behind a substance, which is said to be a submuriat of lead.

The composition of muriat of lead is, according to Klaproth,

Acid 13.5
Oxyd 86.5

10

By Kirwan's account,

Acid 17
Oxyd 83

100

The weight of the atom of muriatic acid being 22, we shall have by Dalton's theory $\frac{95 + 7 + 22}{22} = \frac{100}{17.74}$, by which we have 17.74 acid, and 82.26 of oxyd, which comes very near to Kirwan. When the muriatic acid is poured on the red oxyd of lead, the lead gives up a part of its oxygen to the muriatic acid, constituting the oxymuriatic acid. The muriatic acid then unites with the yellow oxyd thus formed, while the oxygen is returned to the remaining red oxyd, forming the brown oxyd.

The substance above-mentioned, said to be a submuriat, appears rather ambiguous, and may, perhaps, be a mere mixture of the common muriat with the yellow oxyd of lead. There is, however, one argument in favour of its being a proper compound. It is said not to be soluble in water, or that the excess of oxyd is attached to the muriat, so as to prevent its being separated by the affinity of the water for the salt.

The common way of forming this substance is by adding to the muriat of soda a much larger quantity of litharge than would be necessary to saturate the acid of the salt. We are indebted to Vauquelin for the best account of the nature of this anomalous decomposition. At the same time the muriat of lead is decomposed by soda. We have the fact before our eyes, that an oxyd of lead will completely decompose the muriat of soda. If we state the experiment of Vauquelin we shall be better able to give an opinion. To one part of muriat of soda he added seven of litharge in fine powder, with as much water as made the mixture of the consistency of thin soup. This was frequently stirred for several hours. The litharge gradually lost its colour, and ultimately became white. It increased in bulk, and so much water was absorbed as to make it necessary to add more. At the end of four days the chemical action had entirely subsided, when the result was examined. The liquid part, when separated by the filtre, had a strong taste of soda, with a taste of muriat of lead, but no muriat of soda was present. The liquid afforded crystals of carbonat of soda by evaporation. The substance from which the liquor had been separated, when washed and dried, was of a dirty white colour, and was found to have increased in weight $\frac{1}{4}$th of the whole oxyd employed. When this substance was heated to a certain degree it assumed a fine yellow colour, by which it lost $\frac{1}{18}$th of its weight. This was, perhaps, carbonic acid and water.

Some caustic soda was added to a part of this substance, which changed its colour to that of a dirty yellow, and the residuum was found to be a mass of crystals of muriat of lead. By the test of an alkaline hydro-sulphuret, the soda appeared to hold a great quantity of the oxyd of lead in solution.

The one part of muriat of soda, used in this experiment, consisted of .44 of acid, and .56 of soda. The .44 acid would combine with 2.4 of the yellow oxyd to form 3.84 of muriat of lead, leaving $7 - 2.4 = 4.6$ of oxyd of lead. This is supposing the true muriat to be formed; but if a submuriat were formed, it must consist of more than one atom of lead united to one of acid. Suppose it one of acid to two of oxyd, then $.44 + 2 \times 2.4 = .44 + 4.8 = 5.2$ of submuriat, still there would be free oxyd left. But the author tells us that the yellow substance was insoluble in water, or that the water would not take the muriat from the excess of oxyd, although the nitric acid, as well as the soda, was capable of that effect. If there were no free oxyd when two atoms of lead were to one of acid, let us suppose them three to one, we shall then have $.44 + 3 \times 2.4 = .44 \times 7.2 = 7.64$ of a second submuriat. If, therefore, we are to rely upon the fact, that the muriat of lead could not be dissolved, leaving the excess of oxyd, we must regard

this yellow substance as a legitimate compound. If the contrary be the case, we must regard it as a mixture of the true muriat mixed with the yellow oxyd of lead. This substance has been manufactured under a patent by Mr. Turner, of Newcastle-upon-Tyne, and is deemed a valuable pigment for painting.

Phosphat of Lead.—The phosphoric acid does not act upon lead in the cold, and but very feebly by heat. The result of this action is the formation of an insoluble compound, which is the phosphat of lead.

This salt may be more easily formed by adding together the solutions of phosphat of soda and the nitrat, or acetat of lead. A dense white powder subsides, which is the salt in question. This salt is insoluble in water, but it dissolves readily in nitric, and also, when assisted by heat, in the muriatic acid. On the latter solution cooling, crystals of muriat of lead are deposited; a proof that a partial decomposition takes place. It is also decomposed by the sulphuric acid, by the assistance of heat.

When this salt is heated it melts, and on cooling assumes a crystalline appearance.

It is from this salt that phosphorus is generally obtained; for when it is exposed to a great heat, in an earthen retort, with charcoal, both the lead and the phosphorus lose their oxygen, the latter being distilled over.

Mr. Dalton makes the atom of phosphoric acid to weigh 23, then $\frac{95 + 7 + 23}{23} = \frac{100}{18.4}$; so that this salt, from these data, consists of 18.4 of acid, and 88.6 of oxyd, which is very near the proportions of the native salt.

Carbonat of Lead.—Carbonic acid does not act upon lead, but it combines with the yellow oxyd of lead, forming an insoluble white powder, which is manufactured under the name of *white lead*.

This salt may be formed by adding a carbonat of potash to the acetat or nitrat of lead. The precipitate, being washed and dried, is snowy-white powder, appearing to the eye well calculated to make a much finer white paint than that made in the common way. Although the carbonat formed by precipitation is, no doubt, chemically the same with the manufactured, their difference, in point of density, is very remarkable. The proportions of the constituents of this salt are, according to Bergman, 16 acid, 84 oxyd; to Chenevix, 15 acid, 85 oxyd; Proust, 16.15 acid, 83.85 oxyd; and Klaproth, 16.33 acid, 83.67 oxyd in the 100.

The manufacture of white lead has been known long before any idea was entertained of its composition, or the theory of the process; and it is rather singular that no more improvement has been made in the common process, which has long appeared to chemists as clumsy and uneconomical.

The process consists in exposing thin sheets of lead to the fumes of vinegar at a certain temperature. The lead is cast into sheets about two feet long, five or six inches broad, and about ⅛th of an inch thick. These are coiled up, rather spirally, into a cylindrical shape, about five or six inches diameter. The vinegar is placed in the bottom of earthen pots, which are different in size at different manufactures; some holding three pints and others five or six. There is a ledge round the pot, in the inside, about an inch deep, for the purpose of supporting the cylindric coil of lead, which stands upon it like a chimney. The pots thus fitted, with the lead and vinegar, are arranged in rows, upon a stratum of horse-litter, or, what is now used as being cheaper, the refuse bark of tanners. The ends of all the cylinders of lead are covered with a plate of the same metal, to confine the whole as much as possible to the action of the vapour. The pots thus placed are covered over with litter or bark, and a new stratum of pots arranged in a similar way over them. Several tons of lead are sometimes exposed in this manner at one time. The heat arising from the fermentation of the vegetable or animal matter keeps up a certain temperature, by which the vinegar is slowly evaporated. The vapour oxydates the lead, and the oxyd combines with carbonic acid. This latter substance was formerly thought to be furnished by the fermenting substance in which the pots were imbedded: it is now, however, known, that the vinegar is decomposed, and furnishes the carbonic acid. White-lead works are at present carried on, both on the continent and in this country, in which the heat is furnished by artificial means only; and of course the carbonic acid can come from no other source than that of the vinegar.

After the lead has been exposed to the vapour of the vinegar for about six weeks or two months, the pots are withdrawn, and the coils of lead are found corroded to a considerable thickness. The white carbonat thus formed is very brittle and very hard. The sheets are now passed through rollers for the purpose of breaking the white lead from the uncorroded metallic lead. The powder is now taken to a pair of stones, and ground in a manner similar to corn. After this it is levigated to get it of the greatest possible fineness, and it is then gradually dried in stoves for the purpose.

Density and whiteness are the most valuable properties of white lead. These properties do not depend upon the proportions of its elements, but upon the mechanical treatment. The density in all probability will be greater, as it has been longer forming, by the action of the vinegar being slower. Some of the pieces of white lead, as they are separated from the sheet, are much harder than others, even in the same bed. This hardness and density are sometimes so great as to render the pieces sonorous. In this state it is the most valuable. Hence the whitest and densest pieces are selected for making the beautiful substance called *flake white*.

The value of white lead is easily ascertained by the painters, from the quantity of oil required to give it proper consistency. The greater the proportion of lead to the oil, the greater is said to be the body of the paint, and the greater will be its whiteness. The carbonat of lead made by precipitation, when in a dry state, is much whiter than the best white lead, made in the common way. If, however, equal weights of the two be mixed with oil to make them fit for painting, the precipitated specimen will be found to take a much greater quantity of oil than the other, and its whiteness much diminished. The common white lead will have lost so little of its whiteness, that the contrast will be very strikingly in favour of the latter. This fact is exceedingly apparent, on mixing together transparent media of different densities. The whiteness of snow depends upon the mixture of small particles of ice with air; for when the same are mixed with water, the whiteness disappears. All colourless transparent bodies become white on being reduced to powder. This is observed in pounded glass and in salts which lose their water of crystallization. Whiteness may therefore be said to arise from a confused refraction of light, rather than from reflection. See LIGHT.

Fluat of Lead.—Fluoric acid does not oxydate lead; but it is capable of combining with the yellow oxyd, forming this salt, which is an insoluble compound. It may be

formed better by adding the fluat of ammonia to nitrat or acetat of lead, the fluat of lead falling down in a ftate of powder.

Borat of Lead.—Boracic acid does not act upon lead. This falt, however, may be formed by adding a folution of borat of foda to nitrat of lead. The borat of lead will be precipitated in the form of an infoluble white powder. This falt, from a vitreous ftate which the acid is capable of affuming, melts into a colourlefs glafs before the blowpipe.

Acetat of Lead.—Acetic acid has little or no action upon lead when the metal is immerfed in it; but the fumes of the acid in contact with air is capable of oxydating lead, as we have fhewn in the manufacture of white lead. The oxyd thus formed is eafily taken up by the acetic acid, forming a foluble compound of a fweetifh and aftringent tafte. If the folution be evaporated, an excefs of the acid being prefent, the falt is obtained in needle formed cryftals, and of the luftre of fatin. It diffolves in about four times its weight of water at 60°. It is fingular that this falt is decompofed by the carbonic acid. It is from this circumftance that we always find it decompofed, in fome degree, by diffolving it in water, which generally contains more or lefs of that fubftance. This falt is ufed in medicine, uncryftallized, under the name of *Goulard's extract*.

The acetat of lead is an article of extenfive manufacture in England, France, and Holland.

Common diftilled vinegar is firft faturated with the yellow oxyd of lead, which is fometimes from the carbonat or white lead, and frequently from litharge: the latter, however, is the cheapeft procefs. The folution fhould have a little excefs of acid, elfe it does not form the real falt. By flow evaporation this folution cryftallizes, in which ftate it is ufed in abundance in the arts, particularly by the calico printers, for the purpofe of getting the acetat of alumine, by double decompofition with alum.

The analyfis of this falt, according to Dr. Thomfon, is

26 Acid
58 Yellow oxyd
16 Water

100

From the combinations of the acetic acid, the earths, and alkalies, it appears that the weight of its atom is about 36. We have hence $\frac{102 + 36}{36} = \frac{100}{26}$, which gives 26 of acid and 74 of yellow oxyd = 100.

Subacetat of Lead.—When the laft falt is boiled for fome time with the yellow oxyd of lead, a peculiar falt is formed, confifting of two atoms of oxyd, and one of acid. It is lefs foluble in water than the acetat. It was firft noticed by Thenard, to whom we are indebted for the following analyfis:

17 Acid
78 Oxyd
4 Water.

If it confifts of two atoms of bafe to one of acid, its analyfis, according to the data in the acetat, will be $\frac{2 \times 102 + 36}{36}$

100 which gives 15 acid, and 85 oxyd = 100.

Oxalat of Lead.—This falt is formed by diffolving the oxyd of lead in oxalic acid. In all probability there are two falts of this fpecies. That given by Dr. Thomfon is formed with the fecond oxyd, and an excefs of acid, and is the fuperacetat. According to Bergman's analyfis it contains

41.2 Acid
58.8 Red oxyd

100

The weight of the atom of oxalic acid appears to be 39, and an atom of the oxyd in this falt 95 lead + 14 oxygen = 109, therefore fuppofing it the fuper falt $\frac{95 + 14 + 39 \times 2}{39 \times 2} = \frac{100}{41.7}$, which gives 41.7 acid, and 58.3 red oxyd = 100.

The proper oxalat of lead may, no doubt, be formed by an alkaline oxalat being added to the nitrat of lead, the falt being precipitated in a ftate of infoluble powder. From the above data it ought to confift of 27.7 and 72.3 yellow oxyd.

Tartrat of Lead.—The tartaric acid does not act upon lead; but this falt may be formed by adding an alkaline tartrat to the acetat, or nitrat of lead. The tartrat of lead falls down in the form of white powder. Dr. Thomfon gives the analyfis of this falt at 37.44 acid, and 62.56 yellow oxyd.

Citrat of Lead.—This is an infoluble compound, formed by adding an alkaline citrat to a foluble falt of lead.

Malat of Lead.—Malic acid has no action on lead; but the acid combines with the oxyd, forming a compound infoluble in water, but foluble in acetic acid. Cyder, which contains an abundance of malic acid, would never contain lead, but from the prefence of acetic acid. If acetat of lead be dropped into cyder, a copious precipitate falls down, but if free acetic acid be added, the precipitate is diffolved.

Arfeniat of Lead.—The arfenic acid is capable of oxydating lead, and then combines with its oxyd, forming arfeniat of lead, which is completely an infoluble compound. It may alfo be formed by adding the arfeniat of potafh to a foluble falt of lead. From the analyfis of Chenevix it confifts of 33 acid, 63 yellow oxyd, and 4 of water. According to Thenard, it is compofed of 35.7 acid, and 64.3 of oxyd. See the native arfeniat of lead under the mineralogical part of this article.

Molybdat of Lead.—The artificial falt of this fpecies has been little examined. See the native falt.

Chromat of Lead.—This falt may be formed by adding an alkaline chromat to a foluble falt of lead. The falt is precipitated in the form of powder of a reddifh-yellow colour. It is foluble in potafh and foda, from which it may be precipitated without changing its properties. It is foluble in nitric acid, but it is decompofed by the muriatic and fulphuric acids. See native falt.

The other fpecies of the falts of lead are not of importance.

The alkalies and fome of the earths diffolve the oxyd of lead.

Potafh and foda, when pure, diffolve the greateft proportion. By expofure to the air, however, the carbonic acid of the atmofphere combines with the oxyd of lead, as well as the potafh. The lead is precipitated in a ftate of carbonat.

Thefe alkaline folutions of lead have the property of ftaining hair, wool, and horn. The tint commences with a light fawn colour, and ultimately becomes of a deep and beautiful reddifh-brown. Thefe colours are not permanent, being quickly faded by expofure to the light and the air.

Lime water, and probably solutions of barytes and strontian, dissolve the oxyd of lead, but in smaller quantity. A liquid formed by boiling lime and litharge in water, has also the property of staining wool, but the colour is somewhat different to that given by the alkaline solution. The brown colour has less of the red and more of the yellow tint. A composition of common pearl-ash, red lead, and quick lime, is used to give horn the appearance of tortoise shell. In effect, this composition is a solution of the oxyd of lead in potash.

Lead, as we have already seen in the preceding part of this article, is much used in building, particularly for covering, gutters, pipes, and in glass windows. For which uses, it is either cast into sheets in a mould, or milled; which last, some have pretended, is the least serviceable, not only on account of its thinness, but also because it is so exceedingly stretched in milling, and rendered so porous and spongy, that when it comes to lie in the hot sun, it is apt to shrink and crack, and consequently will not keep out the water. Others have preferred the milled lead, or flatted metal, to the cast, because it is more equal, smooth, and solid.

The lead used by glaziers is first cast into slender rods, twelve or fourteen inches long, called *canes*; and these, being afterwards drawn through their vice, come to have a groove on either side for the panes of glass; and this they call *turned* lead.

The method of paling or soldering lead for fitting on of imbossed figures, &c. is by placing the part whereon the figure is to be paled horizontal, and strewing on it some pulverized resin; under this they place a chafing-dish of coals till such time as the resin becomes reddish, and rises in pimples; they apply the figure, and rub some soft solder into the jointing; when this is done, the figure will be paled on, and as firm as if it had been cast on.

Lead is much used in varnishes and painting with oil, both as a colour and as a dryer. It is also used in the preparations of enamels and of porcelain as a flux, and makes the basis of the glazing of almost all pottery wares; and by means of lead the most perfect metals are refined and assayed.

Lead, in *Medicine*. This metal is celebrated by some chemical writers for its great medical virtues; but after all it seems to be a metal which ought to be given internally with the greatest caution, and to be rather calculated for outward application. Its ore is so poisonous, that the steam arising from the furnaces where it is worked, infects the grass of all the neighbouring places, and kills the animals which feed on it. The poisonous quality of this ore is such, that the people who live in the countries where it is dug, and near the places where it is washed, can keep neither dog nor cat, nor any kind of fowl, but all die in a short time, and it has been known that a little house, in which lead ore had been kept for some time, though afterwards made very clean, and bedded with fern, infected calves which were put into it, so that all died in a very short time; and it is a too melancholy observation, that children often die strangely and suddenly about these places. Philosophical Collections, N° 2. p. 6.

Its best preparation is *saccharum saturni*, or the super-acetate of lead; which, though capable of doing great good in hæmorrhages, and some other cases, is apt, however, to bring on colics of so violent a kind, that the remedy often proves worse than the disease.

The internal use of lead is dangerous, on account of the colics and palsies that are occasioned by it. Culinary vessels, lined with a mixture of tin and lead, which is the usual tinning, are apt to communicate to acid foods pernicious qualities, and require to be used with great precaution. The same thing has been also said of liquors kept in glazed ware, and of cyder made in vessels, where lead is used, and of wines adulterated with litharge, &c. See the article Lead, *supra*, and Colica *Pictonum*.

M. Navier has lately discovered that the liver of sulphur, and particularly liver of sulphur of Mars, is an excellent antidote against the poison of lead; and he advises patients labouring under its pernicious effects to drink largely of acidulated liquors, to make afterwards the liver of sulphur the principal part of the cure, and to finish the cure with gentle purgatives.

The Dutch have been charged with correcting the more offensive expressed oils, as that of rape seed, so as to substitute them for oil olive or oil of almonds, by impregnating them with lead: in order to detect this abuse, mix a little of the suspected oil with a solution of orpiment made in lime-water: on shaking them together, and suffering them to rest, the oil, if it has any saturnine taint, will appear of an orange-red colour: if pure, of a pale yellowish. The lead is discovered in wines by the same sulphureous solution, which changes the colour of wines impregnated with this metal to a brownish red or a blackish hue. However, the various preparations of lead are applied externally with safety and great benefit, on account of its sedative, drying, and repellent qualities. The vinegar and sugar of lead, and all the ointments and plasters which contain ceruss, minium, or litharge, eminently possess these qualities. See the following articles and references.

For the laws relating to lead, and the stealing of it, see 27 Ed. III. stat. 2. c. 1. 3. 15. 38 Edw. III. stat. 1. c. 6. 4 Geo. II. c. 32. 29 Geo. II. c. 30. See Larceny.

Lead, *Black*. See Plumbago.

Black lead in fine powder may be readily mixed with melted sulphur, and though the compound remains fluid enough to be poured into moulds, it looks nearly like the coarser sorts of black lead itself. This was probably the method by which prince Rupert is said to have made black lead run like a metal in a mould, so as to serve for black lead again. Birch's Hist. Royal Soc. vol. iii.

The German black-lead pencils, and those which are hawked about among us, are prepared in this manner: their melting or softening, when held in a candle, or applied to a red-hot iron, and yielding a blueish flame, with a strong smell like that of brimstone, discovers their composition. Pencils of this kind are hard and brittle, and cut or scratch the paper or wood instead of marking them. The true English pencils are formed of black lead alone, sawed into slips, which are fitted into a groove made of the softest wood, as cedar, and another slip of wood glued over them. These pencils, however, are of different quality, on account of different sorts of the mineral being fraudulently joined together in one pencil, the fore-part being commonly pretty good, and the rest of an inferior kind. To avoid these inconveniences, some take the finer pieces of black lead itself, which they saw into slips, and fix for use in port-crayons. Lewis's Commerce of Arts, p. 328.

By our laws, entering mines of black lead, with intent to steal it, is made felony. See 25 Geo. II. c. 10. See Larceny.

Lead, for the *manufacture of*, see Plumbery.

There are various preparations of lead, serving for various purposes, some of which are now disused, and others, under one form and name, or another, still continued.

Lead, *Balsam of*, an external medicine, formerly famed for its effects in old and sharp ulcers. It is made by mixing one ounce of sugar of lead with two of oil of turpentine, and setting this mixture in a sand-heat till the salt is dissolved. By this means the oil acquires a red colour, and is called balsam of lead.

Lead, *Burnt*, *plumbum ustum*, is a chemical preparation used in medicine, made of plates of lead, melted in a pot with sulphur, and reduced by fire into a brown powder.

Lead continued in fusion and stirred, so that fresh surfaces may be exposed to the air, will gradually change into a powdery dusky-coloured calx, bearing this name.

Burnt lead is only intended for external use. It has the same virtues ascribed to it, in ointments and plasters, as litharge or minium. Mixed into an unguent with lard alone, it makes a good ointment for the piles.

Lead, *Butter of*, is a kind of liquid unguent made of vinegar and lead, incorporated with roseate oil, and commended for the cure of tetters. It is called *butyrum saturni*.

Lead, *Calcined*, or *calx of lead*. See Calx, Cerusse, Glass *of Lead*, Litharge, Massicot, Minium, &c. and *Alloys of* Lead, supra.

Lead, *Casting of*. See Casting.

Lead, *Cerate of Super-acetate*, *Ceratum plumbi super-acetatis*, the " Unguentum cerussæ acetatæ" of P. L. 1787, is prepared in the following manner: Take of super-acetate of lead two drachms, white wax, two ounces, and olive oil, half a pint. Dissolve the wax in seven fluid-ounces of oil, then gradually add to it the super-acetate of lead, separately rubbed down with the remaining oil, and stir the mixture with a wooden slice, until the whole has united.

Lead, *Compound cerate of*. See Ceratum *lithargyri acetati compositum*.

Lead, *Cohesion of*. See Cohesion.

Lead *Dust* is a preparation used by the potters; made by throwing charcoal dust into melted lead, and stirring them a long time together: to separate the coal again, they only wash it in water, and dry it afresh. Its use is, to give a varnish and gloss to their works.

Lead, *Extract of*, or *Saturn*, is prepared by simmering together as many pounds of the litharge of gold as quarts of vinegar for an hour and a quarter, and often stirring them; then taking it from the fire, and as soon as it is cool enough, pouring the clear liquor into bottles to be kept for use. If this liquor be made into the common consistence of an extract, it must boil yet longer after its separation from the mass, and will acquire a reddish colour. This is Goulard's extract (see Lead, *supra*), and the basis of all his preparations of lead. It evidently differs in no respect from sugar of lead, and vinegar of litharge, but in the degree of concentration The only circumstance in which the extract seems to have the advantage of sugar of lead, appears to be in the greater quantity of the acetous acid contained in it, which proves an excellent assistant in many cases, and the sugar of lead, when once crystallized, cannot be brought back to that state of solution in vinegar in which it was before; yet where a large quantity of watery menstruum is added, as in Mr. Goulard's saturnine water, it is as well to make a solution of sugar of lead in the water, and add the vinegar afterwards, as to mix them both together in the form of extract. Aikin's Obs. on the external Use of Preparations of Lead, &c. p. 2. See Vinegar *of Lead*.

In the London Pharmacopeia of 1787, this was denominated " Aqua lithargyri acetati;" and in the last edition it is called " Liquor plumbi acetatis," or " solution of acetate of lead," and it is directed to be prepared by mixing two pounds four ounces of semi-vitreous oxyd of lead, with a gallon of acetic acid, and boiling down to six pints, constantly stirring; then setting it by, that the feculencies may subside, and straining. This is a dense liquor, of a deep brown colour, and consists of a saturated solution of subacetate of lead. It was restored in the last Pharmacopeia, in consequence of the celebrity it had obtained under the name of " Goulard's Extract." The " Aqua lithargyri acetati composita" of P. L. 1787, called in the last edition " Liquor plumbi acetatis diluti," or " diluted solution of acetate of lead," is prepared by mixing a drachm of solution of acetate of lead, a pint of distilled water, and a fl.-drachm of weak spirit. When this mixture is made, even with distilled water, some precipitation takes place; and when, as is more common, ordinary water, containing any muriates or sulphates, is used, this is much more abundant from double decomposition, and gives the liquor a milky appearance when diffused through it. To this it owes its common name of " white wash."

Lead, *Glass of*. See Glass *of Lead*.

Lead, *Magistery of*, is the calx of lead purified and subtilized. It is made of lead dissolved in aquafortis, pouring filtrated salt water into it; whence results a magistery extremely white, which, when softened by several lotions, is mixed with pomatums for the face and complexion.

Lead *Mine*. See Mining.

Lead, *Mock*, a name given to a glittering substance found in lead-mines. See Galena *inanis*, and Blinde.

Lead, *Native*. See Lead, *supra*.

Lead, *Ointments of*, *Preparations of*. See Unguent.

Lead *Plaster*. See Emplastrum *Commune*.

Lead *Pipes*, *Manufacture of*. The common method used for making lead pipes, consists in casting the lead upon a smooth steel mandril placed in a mould, also of metal, to form the outside. These pieces are about 18 inches long. They are afterwards joined together by a process, called *lining*.

A very great improvement has been made in the manufacture of lead pipes, by drawing them in a manner similar to wire. The lead to form the pipe is cast upon a mandril of the diameter of the inside the pipe, but of such a thickness as to equal the whole pipe in weight: it is then fastened upon one end of a cylindric steel mandril, and the lead is pulled through different sized holes, till the pipe is of sufficient length and thickness. These pipes can be drawn to the length of eight or ten feet. The power required, however, is very great, which is one objection to the method. They are also liable to flaws; for, if the casting happen to be imperfect, the imperfection is much increased and extended by the process of drawing.

This manufacture has been much improved by passing the lead upon the mandril, through grooved rollers of different sizes, following each other in succession. The power required is much less than that required for drawing; and the pipes are said to be superior in other respects. For a more particular account of this manufacture, see *Lead* Pipes.

Lead, *Red*, a preparation of mineral lead calcined and rubified; used by painters, potters, and surgeons. See Minium, and *Oxyds of* Lead.

Lead, *Salt* or *Sugar of*, *Saccharum saturni*, *Superacetas plumbi*, *superacetate of lead*, is an essential salt of vinegar, incorporated with the proper substance of lead, or ceruss, dissolved in spirit of vinegar. See Saccharum *Saturni*, and Lead, *supra*.

Leather

LEATHER, in *Commerce*, the ſkins of ſeveral ſorts of beaſts dreſſed and prepared for the uſe of various manufacturers, whoſe buſineſs is to make them up, according to their different employments. The butcher and others, who flay them off the carcaſes, diſpoſe of them raw or ſalted to the tanner and tawer; they to the ſhamoy, morocco, and other kind of leather-dreſſers, who prepare them according to their reſpective arts, in order to vent them among the curriers and leather-cutters, glovers, harneſs-makers, coach-makers, ſadlers, breeches-makers, gilt-leather-makers, chair-makers, ſhoe-makers, book-binders, and all in any way concerned in the article of leather.

Leather has divers names according to the ſtate wherein it is, and according to the different kinds of ſkins of which it is prepared, and its peculiar qualities when ſo prepared. 1. The ſkin is raw as it comes off the animal. 2. Some are ſalted with ſea-ſalt and alum, or with natron, which is a ſpecies of ſalt-petre, or white ſalt-wort, to prevent corruption in keeping, or ſending to diſtant tanneries during hot ſeaſons

Skins dried with the hair on, are commonly thoſe of oxen and cows, or buffaloes, either tame or wild. Moſt of thoſe in France come from foreign countries. The places which furniſh the largeſt quantity, are Peru, the iſle of St. Domingo, Barbary, Cape Verde Iſles, the river Senegal in Africa, Muſcovy, Ireland, the iſland of Cuba. Thoſe of this latter place are the moſt eſteemed; they are called Havannah ſkins, from the name of the capital city of that iſland, whither they are carried in order to be ſent to Spain, and from thence into other parts of Europe. After theſe ſkins are ſtript of their hair, they are ſold to the tanners. See CURRYING, TANNING, and SKINS.

The three principal aſſortments of leather are tanned or tawed, and oil and alum leather, all which are dreſſed in ſome yards.

The art of dreſſing leather in oil conſiſts in firſt ſoaking the ſkins; then throwing them into the lime-pit; and when they are taken hence, pulling them and delivering them to the friezer; they are then ſtruck with the oil, and ſent to the mill; when they are milled ſufficiently, they are thrown into the ditch to be ſcoured, and by ſome ſcudded, and afterwards hung upon the hooks to dry. When they have been weighed and marked by the proper officers, in order to fix the exciſe duty, they are fit for ſale. The ſorts of ſkins dreſſed in oil are thoſe of deer, ſheep, and lambs, and ſome few of goat, and the oil uſed for this purpoſe is Newfoundland, or cod's liver oil. The alum leather-dreſſers' art conſiſts in properly ſoaking, liming, wringing, (an operation ſometimes omitted,) and ſtriking them in a liquor compoſed of water, ſalt, and alum, and then drying them properly. The ſorts of ſkins dreſſed in alum are thoſe of ſheep and lambs, and a large quantity of kid. Poſtleth. Dict. Com. art. *Leather*.

There are ſeveral ſtatutes relating to leather; the 27 Hen. VIII. c. 14. directs packers to be appointed for leather to be tranſported: but the 18 Eliz. c. 9. prohibits the ſhipping of leather on penalty of forfeiture, &c. Though by 20 Car. c. 5. tranſportation of leather was allowed to Scotland, Ireland, or any foreign countries paying a cuſtom or duty; which ſtatute was continued by divers ſubſequent acts.

No perſon ſhall ingroſs leather to ſell again, under the penalty of forfeiture. None but tanners are to buy any rough hides of leather, or calves' ſkins in the hair, on pain of forfeiture; and no perſon ſhall foreſtall hides, under the penalty of 6*s*. 8*d*. a hide. Leather not ſufficiently tanned is to be forfeited. In London, the lord mayor and aldermen are to appoint and ſwear ſearchers and ſealers of leather out of the company of cordwainers, &c. and alſo triers of the ſufficiency of leather; and the ſame is to be done by mayors, &c. in other towns and corporations; and ſearchers allowing inſufficient leather, incur a forfeiture of 40*s*. Shoemakers making ſhoes or boots of inſufficient leather are liable to forfeit for every pair 3*s*. 4*d*. and the value thereof. (1 Jac. I. c. 22.) Red tanned leather is to be brought into open leather markets, and ſearched and ſealed before it be expoſed to ſale, and on ſale is to be regiſtered, or ſhall be forfeited; and contracts for ſale otherwiſe to be void. (13 & 14 Car. II. c. 7.) Hides of leather are adjudged the ware and manufacture of the currier, and ſubject to ſearch, &c. All perſons dealing in leather may buy tanned leather, ſearched in open market, and any perſon may buy or ſell leather, hides, or ſkins, by weight. 1 W. & M. c. 33.

The firſt ſtatute concerning leather, which it is neceſſary for us to refer to in this article, is the 1 Jac. c. 22, which reduces all preceding acts relating to that commodity into one; and therefore to this we ſhall have a retroſpect in the progreſs of this article; premiſing that all forfeitures by this act, not otherwiſe ſpecially directed, ſhall be divided, one-third to the king, one-third to him that ſhall ſue, and one-third to the city, town, or lord of the liberty. By 9 Ann. c. 11. any two juſtices near the place where the forfeitures are incurred, or offence committed, may hear and determine the ſame. All forfeitures, by the act of 13 & 14 Car. II. c. 7. ſhall be recovered in any court at Weſtminſter, or in any court of record in the city, &c. where the offence ſhall be committed; to be diſtributed half to the king, and half to the informer. By 39 & 40 Geo. III. c. 66. it is enacted that proper places and times for inſpecting all raw hides and ſkins of cattle, ſheep, horſes, and hogs, ſhall be fixed by the mayor, bailiff, or head-officer of any city, town corporate, borough, or market-town, or any two magiſtrates acting for the ſame, or any two juſtices acting for the diviſion within or neareſt to ſuch city, &c. The manner of appointing inſpectors is alſo preſcribed by the ſaid acts. And by the ſame, butchers, &c. who are chargeable with wilfully or careleſsly injuring hides, ſo as to make them leſs valuable, are liable to penalties, not exceeding 5*s*. (41 Geo. III.) nor leſs than 1*s*. for the raw hide of every ox,

bull, cow, or heifer, &c.; and not exceeding 2s. 6d. (41 Geo III) nor less than 6d. for the skin of every calf; and not exceeding 2s. 6d (41 Geo. III.) nor less than 1s. for the hide of every horse, mare, or gelding; and not exceeding 6d. nor less than 3d. for the hide of every hog, pig, sheep, or lamb. Inspectors are required to take a prescribed oath, and are allowed certain fees for examining and inspecting hides. &c. (See also 43 Geo. III. c. 106.) These inspectors may impose penalties for damaging hides, &c.; which penalties shall be recovered before a justice, one-half of which, by 41 Geo. III. c. 53. shall be given to the inspector, and the other half applied to the purpose of better carrying on the objects of these acts. By the above-cited acts, 39 & 40 Geo III. c. 66, the inspectors of raw hides shall provide proper stamps, and stamp the hides, not damaged or otherwise; and seize such hides or skins as have been damaged, and sell the same, provided the penalties be not paid in less than 48 hours after such seizure. Butchers or others neglecting to bring hides to be marked, shall forfeit not exceeding 5l. nor less than 40s. for every such hide. The regulations of this act shall extend to all hides found in Great Britain. (41 Geo. III. c. 53.) All disputes shall be settled by any five impartial and respectable persons concerned in the manufacture of leather, summoned by a magistrate, before whom such dispute shall be brought. All penalties and forfeitures shall be recovered before one justice or magistrate of any city, town, or place, where the offence shall be committed, upon conviction, confession, or the oath of one witness, and levied by distress; and for want of sufficient distress, the offending party shall be committed by such justice or magistrate to the common gaol or house of correction, for a time not exceeding one month. All penalties and forfeitures, not otherwise disposed of, shall go, half to the informer, and half to the execution of the purposes of the act. Persons aggrieved may appeal to the next sessions. (39 & 40 Geo. III. c. 66.) By the same and 41 Geo. III. c. 53. informations for offences against this act for wilfully or carelessly gashing raw hides, shall be laid within three days after the commission of the offence; and for any other offence within 14 days after the offence committed. By 43 Geo. III. c. 106. the provisions of 39 & 40 Geo. III. c. 66. and 41 Geo. III. c. 53, are extended to London, Westminster, and Southwark, and to all places within fifteen miles of the Royal Exchange. All raw hides within five miles of the Royal Exchange shall be brought to Leadenhall market, and the skins of sheep and lambs to one of the three sheep-skin markets in Southwark, the Whitechapel market, or the market at Wood's Close. Proper places and hours for inspection are to be appointed within three months after the passing of this act. For the market at Leadenhall, eight inspectors are to be appointed; four from the company of butchers, two by the company of curriers, and two by the company of cordwainers; and besides, there shall be appointed four inspectors for the sheep market at Wood's Close, two for Southwark, and two for the market of Whitechapel. One half of the inspectors at each of the three last-mentioned markets to be appointed by the company of butchers, and the other half at each of such markets in equal proportions by the companies of curriers and cordwainers. Provision is made for increasing their number and regulating their attendance. Inspectors for Leadenhall market are required to attend on the usual market days, from six in the morning till five in the afternoon, from the 25th of March to the 29th of September; and from seven in the morning until four in the afternoon, from the 30th of September till the 24th of March.

The distribution of fines and fees is prescribed, so that one-half shall be equally divided between the inspectors, acting at the respective markets, and the remaining half-part shall be paid weekly to the arbitrator of the market, in respect to which they are received, and paid monthly by the said arbitrators to the respective persons appointed by the courts of assistants to receive the same. There is a penalty for impeding inspectors, not exceeding 5l. nor less than 10s. for each offence, and also a penalty not exceeding 20l. on inspectors receiving, and persons offering bribes. Salesmen are required to deliver an account of hides or skins sold, under a penalty for every offence of 10l. The lord-mayor of London is empowered to increase the fees of the inspectors, under the representation of the courts of assistants of the companies concerned, to any sum not exceeding 1d. for every hide, ½d. for every calf-skin, hog-skin, or pig-skin, and ¼d. for every sheep or lamb-skin. The respective courts of assistants are required to appoint annually four arbitrators, to settle disputes arising in any of the markets above-mentioned; and these arbitrators are empowered to fine inspectors, and also butchers and salesmen, for frivolous decisions and exorbitant impositions. Inspectors and arbitrators are liable to be dismissed for misconduct in their respective offices, or to a fine not exceeding 5l. nor less than 10s. Buyers and sellers of unstamped hides or skins are liable to a forfeiture not exceeding 20s. nor less than 5s. for every hide; and not exceeding 5s. nor less than 1s. for every skin of hogs, pigs, or calves; and not exceeding 1s. nor less than 6d. for every sheep or lamb-skin. The treasurers are appointed by the respective courts of assistants to receive the sums collected by the arbitrators; one-half of which shall be paid to the treasurer appointed by the company of butchers, one-fourth to the officer of the company of curriers, and one-fourth to the officer of the company of cordwainers; which sums shall first of all be applied for the execution of the acts, and to the use of the poor of the said companies.

For particular regulations concerning *tanners* and *curriers* of hides, see these articles respectively. The mayor and aldermen of London (on pain of 40l. for every year they make default, half to the king and half to him that shall sue) shall yearly appoint eight freemen of some of the companies of cordwainers, curriers, sadlers or girdlers, of whom one shall be a sealer, and keep a seal for the sealing of leather; they shall be sworn to do their office truly; and they shall search and view all tanned leather brought to market, whether it is thoroughly tanned and dried: and if it is, shall seal the same. Four of these officers shall be changed every year; no officer shall be continued above two years together, nor be re-elected till after the end of three years, on pain of 10l. a month. A similar regulation extends to other places. The wardens of the curriers shall search and seal curried leather, for which they are entitled to fees, to be paid by the currier; on pain of forfeiture for every hide not searched and sealed, 6s. 8d. If any searcher or sealer shall neglect his office or misbehave, he shall forfeit 40s.: if he shall take a bribe, or exact a fee not appointed, he shall forfeit 20l.; and if he shall refuse to execute his office, he shall forfeit 10l. If any person shall hinder the searcher in the execution of his office, he shall forfeit 5l. (1 Jac. c. 22.) The mayor of London (on pain of 5l. half to the king, and half to him that shall sue) shall, within six days after notice given of any seizure of any leather, red and unwrought, appoint six triers, two of the cordwainers, two of the curriers, and two of the tanners, using Leadenhall market, who, upon their oaths taken before him, shall, on the second or third market-day for leather, try the same, whether it be sufficient or not. The same regulation extends to other places. Triers not doing their duty shall forfeit 5l. The offering for sale of unsearched

and unsealed leather incurs a forfeiture of the same, or its value, and for every hide or piece 6*s*. 8*d*.; and for every dozen of calves' skins, 3*s*. 4*d*.; but no person shall incur any penalty for selling or buying any sheep-skins, unsearched or unsealed. (1 Jac. c. 22. 4 Jac. c. 6.) All red tanned leather shall be bought only in the open fair or market, and not in any house, yard, shop, or other place, on pain of forfeiting the same, or its value, and rendering the contract void: and such leather shall be searched and sealed before sale, and on sale shall be registered, on pain of forfeiting the same, or its value. (13 & 14 Car. II. c. 7) Searchers and sealers shall keep a register of all bargains made for leather, during the fair or market, with the prices; taking for searching, sealing, and registering of every ten hides, or butts, of the seller 2*d*., and so in proportion; and for every six dozen of calves'-skins, or sheep-skins, 2*d*.: and of the buyer after the same rate. Red tanned leather, brought into London, or within three miles of it, shall be brought to Leadenhall, to be viewed and registered by the searchers, with half such fees to be paid for tanned leather bought out of London, or within three miles, and searched and sealed before it be brought within the city; on pain that every person housing, or not bringing his leather to Leadenhall, shall forfeit for every hide or skin 6*s*. 8*d*. No person shall buy any tanned leather, unwrought, but who shall work the same into wares, on pain of forfeiting the same, or value. (1 Jac. c. 22.) But by 12 Geo. II. c. 25, all persons who deal or work in leather may buy all sorts of tanned leather in open fair or market, whether curried or uncurried, being first searched and sealed, and may cut and sell the same in any small pieces in their open shops. (See also 1 W. sess. 1. c. 33.) Within London, or within three miles, no person shall sell any wares appertaining to the mystery of any artificer cutting leather, but only in open shop, common fair, or market, whereby the wardens may have search thereof: on pain of forfeiting the same, and also 10*s*. 1 Jac. c. 22.

No shoemaker shall make any boots or shoes, or any part of them, except of leather, well and truly tanned and curried, or of leather well and truly tanned only; nor put into any part of any shoes or boots, any leather made of a sheep-skin, bull-hide, or horse-hide, &c. &c., on pain of forfeiting for every pair of shoes or boots 3*s*. 4*d*., and the value. And if any artificer using leather do make any wares of any tanned leather insufficiently tanned, or of tanned and curried leather, not sufficiently tanned and curried, he shall forfeit the same, and value. If any shoemaker or cobler within London, or three miles of it, shall put any tanned leather into any boots or shoes, or other things made of tanned leather, which shall not be well and perfectly tanned, or do put any curried leather into boots or shoes, or any things made of leather, which shall not be sufficiently tanned and curried, and also sealed; he shall forfeit the same and value. 1 Jac. c. 22.

All sorts of leather and skin, tanned or dressed, may be exported. 20 Car. II. c. 5. 9 Ann. c. 6.

By 43 Geo. III. c. 69, a duty is laid upon all hides and skins, vellum and parchment, imported; and drawbacks allowed on the exportation of them. Other duties are also imposed by 49 Geo. III. c. 98. for which we refer to the act, sched. A. After the duty on importation shall be paid, the officers of the customs shall cause every hide or skin to be marked, to denote the payment of the duty. (9 Anne. c. 11.) But by 15 Geo. III. c. 35, raw or undressed goat-skins may be imported for five years, duty free; and this act was made perpetual by 31 Geo. III. c. 43. The several duties for and upon all hides and skins, and parts and pieces of hides and skins, tanned, tawed, or dressed, to be paid by the tanners, tawers, and dressers of hides and skins respectively, and the duties upon vellum and parchment, to be paid by the respective makers thereof; and certain drawbacks are allowed on the exportation thereof. By *tanned* hides or skins, or pieces thereof, are meant only such as are tanned in wooze, made of the bark of trees, or shumack; and by hides and skins, *dressed in oil*, are meant such as are made into leather in oil, or with any materials, of which the chief ingredient shall be oil; and by *tawed* hides or skins, are meant such as are dressed or made into leather, in alum and salt, or meal, or other ingredients properly used by tawers of white leather. 9 Ann. c. 11. s. 3.

By 43 Geo. III. c. 69, every tanner shall take out a licence annually, for which he shall pay, if within the bills of mortality, 5*l*., elsewhere 2*l*. 10*s*., on pain of 30*l*. (24 Geo. III. c. 41. Sess. 2. § 1.) And every tawer shall take out a licence annually, for which he shall pay 1*l*. on the penalty of 10*l*. And every dresser of hides in oil shall take out a licence annually, for which he shall pay 2*l*. on the penalty of 20*l*. And every currier shall take out a licence annually, for which he shall pay 2*l*. on the penalty of 20*l*. And every maker of vellum or parchment shall take out a licence annually, for which he shall pay 1*l*. on the penalty of 10*l*. And every person who shall take out such licences shall renew them annually, ten days before their expiration, on the penalties above stated. Collar-makers, glovers, bridle-cutters and others, who dress skins or hides, or pieces thereof, in oil, alum, and salt, or meal, or other ingredients, and who cut and make the same into wares, shall be accounted tawers, or dressers. (2 Ann. c. 11. § 28.) Any hide or skin, which hath once paid the duty, shall not be charged under any other denomination (9 Ann. c. 11. § 3.) The commissioners of these duties, appointed by the commissioners of the treasury, shall have the same power as the commissioners of excise. Tanners, tawers, curriers, or dressers of hides or skins, and makers of vellum or parchment, are required to give notice in writing to the officer, of their names and places of abode, and of their tan-houses, yards, work-houses, mills, or other places where they intend to tan, taw, or dress hides or skins, or make vellum or parchment, before they use the same; on pain of 50*l*. Those who use such places without entry of them, shall forfeit 20*l*., and the goods found in them, or their value, shall also be forfeited. The officers, at all seasonable hours, shall enter and survey these places, and if the owner or occupier refuse them entrance, he shall forfeit 10*l*. And if any hide or skin, tanned, tawed, or dressed in oil, be found in any place not entered, without a stamp denoting that the duty has been charged, the same shall be forfeited and seized; and the persons in whose possession it shall have been found, shall for each offence forfeit 100*l*. (41 Geo. III. c. 91. § 10.) Tanners and others shall give two days notice to the proper officers of the removal of goods to the drying place, that an account of them may be taken; and before they are carried away from the drying place, two days notice shall be given; and they shall be entered with the officer with respect to their number and quality, and verified on oath before a justice of peace, collector or supervisor; nor shall they be removed, till the duty be first charged, entered and marked. The penalty for neglect is 20*l*. and forfeiture of the goods, or their value. Concealment of any hide or skin, vellum or parchment, in order to avoid the duty, incurs a forfeiture of 20*l*. and the goods or their value. If any tanner or other person shall shave any hide or calf-skin, before the same be thoroughly tanned, so as to impair it and diminish the duty, the same or its value shall be forfeited. Tanners or other such person shall keep

juſt ſcales and weights; and the penalty for neglect or not allowing the uſe of them, ſhall be a forfeiture of 50*l.* The uſe of falſe ſcales incurs a forfeiture of 100*l.* (10 Geo. III. c. 44. 28 Geo. III. c. 37.) Cheating or obſtructing officers ſubjects to a forfeiture of 100*l.* (26 Geo. III. c. 77.) When the duties are aſcertained, the officer ſhall enter them in a book, and return them to the commiſſioners, or a perſon appointed by them; and when the duty is ſettled, the officer ſhall cauſe every hide or ſkin, and every piece of both, and all vellum and parchment to be marked. And if the goods be removed before the duty is charged, and they are marked, the penalty is a forfeiture of 50*l.* and the ſaid goods; and any perſon counterfeiting the ſtamps, or knowingly ſelling any of the ſaid goods with a counterfeit ſtamp, is chargeable with felony without benefit of clergy. (9 Ann. c. 11. 5 Geo. II. c. 3. 33 Geo. III. c. 54.) Stamped and unſtamped goods ſhall be kept ſeparate, on pain of 10*l.* (5 Geo. c. 2.) And thoſe that have been ſtamped ſhall not be removed for 24 hours after ſtamping, &c. under a forfeiture of 20*l.* (5 Geo. III. c. 43.) Scales and weights ſhall be kept for reweighing them, and aſſiſtance given to the officer, on pain of 50*l.* Perſons within the bills of mortality ſhall pay off the duties within 14 days to the commiſſioners, and in other places in ſix weeks, after the goods have been marked. (9 Ann. c. 11.) Thoſe who do not pay in this manner ſhall forfeit double duty; and they ſhall not be delivered out till the duty be paid, on pain of double value. Every tanner, and other ſuch perſon, ſhall balance their accounts with the officers once in three months, on pain of 50*l.* Any two juſtices reſiding near the premiſes may hear and determine offences, and order the penalties to be levied by diſtreſs and ſale, if not redeemed in ſix days.

Foreign manufactured gloves imported ſhall be forfeited, and may be ſearched for and ſeized by any officer of the cuſtoms or exciſe; and every perſon importing or vending the ſame, ſhall alſo forfeit 200*l.* with double coſts. 6 Geo. III. c. 19.

Lighthouse

LIGHT-HOUSE, in the *Marine*, is a building or watch-tower erected upon the sea-ſhore, to ſerve as a landmark to mariners in the night, to avoid any rocks or other dangers. The light-houſe is generally a high tower, having at the top an apartment called the lantern, with windows on all ſides, to exhibit the light made within it by the flame of an open fire, or by lamps or candles. It is frequently of ſervice to navigation, to erect light-houſes upon inſulated rocks riſing from the ſea, to warn ſhips of their approach to ſuch rocks. Of this kind are the Eddyſtone rocks off Plymouth, and the Bell rock at the mouth of the Forth in Scotland. In theſe ſituations, the heavy ſwell of the ſea, when agitated by a ſtorm, ſtrikes with ſuch force againſt the building, as to require every precaution to ſecure them from being overthrown by the continued action of ſo powerful an enemy. The Eddyſtone rocks being the moſt celebrated, as well from their peculiarly expoſed ſituation, as from the great ingenuity diſplayed in the conſtruction of the light-houſes erected at different periods upon them, renders them deſerving of particular deſcription. The hiſtory of the different erections has been already given under the head of EDDYSTONE. We here intend deſcribing the conſtruction of each, which will be a ſummary of all the different kinds of light-houſes of wood or ſtone.

Mr. Winſtanley's light-houſe was begun upon the Eddyſtone rock in 1696, and was more than four years in the erection, from the many interruptions of the wind, which from ſome quarters cauſes the ſea to break over theſe rocks with ſuch violence, as to prevent the poſſibility of landing upon them, though the ſea around is very quiet. This is occaſioned by the rocks being open to the ſwell from the Great Atlantic ocean, or from the Bay of Biſcay, in all the ſouth-weſtern points of the compaſs; and is increaſed by the form and poſition of the rocks, which have a regular ſlope to the ſouth-weſt from the deep ſea to the rock upon which the houſe is erected, and which, therefore, receives the uncontrouled fury of theſe ſeas, meeting no other object to break upon, and the effect of ſo great an extent of water, cauſed by the hard S.W. winds, continues for many days, though ſucceeded by a calm, and breaks frightfully upon Eddyſtone. When there is no wind, and the ſurface of the ſea appears ſmooth, Mr. Winſtanley's light-houſe appears, from an engraved plate of it, publiſhed by himſelf, to have been a ſtone tower with 12 ſides, riſing 44 feet above the higheſt point of the rock, which is inclined ſo as to be 10 feet lower on the oppoſite ſide of the houſe. The tower was 24 feet in diameter. At the top were a baluſtrade and platform: upon this eight pillars were erected, and ſupported a dome of the ſame diameter as the tower. From the top of this aroſe a ſmaller octagonal tower, 15 feet in diameter and ſeven in height; and upon this was the lantern 10 feet in diameter, and 12 high, containing the lights. It had a gallery or balcony ſurrounding it, to give acceſs to the outſide of the windows. The whole was ſurmounted by a fanciful iron work with a vane. The entry was by a door at the bottom, which was ſolid ſtone, except the aperture for the ſtaircaſe, 12 feet in height. Above this were three floors, the loweſt being the ſtore-room, the next the ſtate-room, and the third the kitchen. Theſe occupied the height up to the level of the platform, or open gallery above-mentioned. The dome above this contained the lodging-room, and the octagon above it the attending or look-out room, immediately beneath the lantern. This edifice was, as before-mentioned, more than four years in erecting. The firſt ſummer (for it is only in this ſeaſon the rock is acceſſible) was ſpent in making 12 holes in the rock, and faſtening 12 great irons to hold the future work. In the ſecond year, a ſolid pillar 14 feet diameter, and 12 feet

high, was built as a core or centre for the building. The third year the pillar was increafed to 16 feet diameter, and all the work was raifed, which to the vane was at that time 80 feet. The workmen lodged in the houfe foon after Midfummer, but were by bad weather imprifoned 11 days before a boat could relieve them. A light was exhibited on the 14th of Nov. 1698. But finding that the fea frequently broke over the lantern, in the fourth year the whole building was encompaffed with a new work of four feet in thicknefs, made folid for near 20 feet high, and the lantern was raifed 40 feet higher than at firft, making it 90 feet to the top of the cupola of the lantern, above which the vane rofe 22 feet. "Yet after all," Mr. Winftanley fays, "the fea in ftorms flies in appearance 100 feet above the vane, and at times doth cover half the fide of the houfe and the lantern, as if it were under water." The joints of the additional ftone work of the fourth year, appear to have been covered with an iron or copper hoop encompaffing the building, to prevent the fea wafhing out the mortar. The building withftood the wafh of the fea only till the year 1703, when the inventor, being at Plymouth to fuperintend fome repairs of the building, went off to it on fome of his friends intimating the danger of the building, from a ftorm which feemed coming on. He expreffed a wifh that he might be prefent in the moft violent ftorm which ever blew, to obferve its effect on the ftructure. In this he was too amply gratified, for on the 26th of November a violent ftorm arofe, and the next morning no veftige of the light-houfe remained, except fome of the irons which were faftened in the rock, and a piece of iron chain, which was jambed faft into a chink of the rock, and nothing was ever afterwards found. Thus perifhed the firft light-houfe with its ingenious, but unfortunate, builder. A Weft Indian fhip was loft on the rocks foon after the light-houfe was overthrown. This circumftance, and the great utility of the light while exhibited, ftimulated the Board of Trinity houfe, who had the management of the building, to erect another, and an act of parliament, of the 4th of queen Anne, was paffed in 1706, to enable the Board of Trinity houfe to raife duties on fhips to rebuild it, of which they granted a leafe of 99 years to Capt. Lovel, as he engaged to build and maintain the houfe. In July 1706, the work was begun under the direction of Mr. John Rudyerd, who was at that time a filk mercer on Ludgate hill, London, but who appears to have poffeffed much ingenuity and mental refource. He, like Mr. Winftanley, publifhed a print drawn by B. Lens, and engraved by J. Sturt, which informs us, that it was a conical fruftum of wood, formed of 71 upright beams, united together by being bolted to circular kirbs of wood withinfide, upon which kirbs the floors were framed. It, in fome degree, refembled an immenfe conical cafk, but without hoops: the diameter at the bafe was 23 feet, at the top 15 feet, and its altitude, from the higheft point of the rock to the top of the upright, was 62 feet. At the top of the building was a balcony, furrounded by a railing, and in the centre of the area thus formed the lantern was fituated. It had windows on all fides, and was of an octagonal figure, 10 feet in diameter, and 13 high, furmounted by a dome with a fimple ball at top, inftead of the fanciful iron work which ornamented the firft edifice. Mr. Rudyerd, from principles totally different from thofe of his predeceffor, made his building quite plain, without the leaft projection or ornament on which the water could act when dafhing againft it; and he omitted no precaution of uniting all the parts together, and faftening the whole to the rock. As the furface of the rock was naturally inclined, and the whole building would have had a tendency to flide down it, if merely placed upon it, as Mr. Winftanley's was, Mr. Rudyerd wifhed to reduce its furface into level fteps, upon which each timber would have a horizontal bearing; but finding this to be the moft difficult of the whole undertaking, it was imperfectly executed, only five fteps being cut, and thofe did not take out all the inclined furface; however, it was fufficient for the purpofe.

The building was filled up quite folid for 19 feet from the loweft point of the rock, and, excepting the well for the ftair-cafe, was folid to the height of 37 feet. The folid was formed of three beds of moor ftone, with ftrong floorings of timbers between each bed, to unite them with the external uprights. The lower bed contained five courfes of ftone, and was five feet thick; the fecond was the fame, and the third was four feet thick, containing four courfes. The whole erection, in addition to the weight of this ftone, which was about 280 tons, was fecured to the rock by 36 iron cramps, part of them arranged in a circle about a foot within the external uprights, and the remainder, which were fmaller cramps, in an interior circle three feet diftant from the former, to hold down the floors of timber which had the ftone beds between them. In the centre of the building a ftrong maft was erected, fecured by two cramps to the rock at the bottom, and rifing above the folid to the height of 48 feet, being united to the framing of each floor it paffed through, and thus forming a central axis to ftrengthen the whole. The houfe above the folid contained four apartments, the lower being the ftore room, the next the ftate room, the third the bed chamber, and the fourth the kitchen, immediately beneath the lantern. In the manner of fixing the irons to the rock, upon the duration of which the fecurity of the whole work depended, Mr. Rudyerd fucceeded moft admirably. The holes in the rock were made by drilling two holes rather diverging from each other, fo that they would be an inch more afunder at 15 or 16 inches depth, than on the furface of the rock. A third hole being drilled between thefe two, and the three being broken into one, formed a hole larger at the bottom than the top. The iron cramp was formed of two pieces, which, when laid together, were of the fhape of the hole, but when feparated, one was larger at the bottom than the top, and the other fmalleft at the bottom; therefore the former being firft put down into the hole, and the latter driven in by the fide of it, wedged it faft, and both being united by the fame bolts which attached them to the timbers, rendered it impoffible to draw them out. They were put in their places hot, and a quantity of melted tallow being firft poured into the hole, when the hot irons were put down the tallow ran over on all fides, and thus certainly filled up all cavities. A quantity of coarfe pewter, made red-hot, was now poured into the cavity round the irons, and, being a heavier fluid, difplaced the tallow, and filled the fpace round them completely, the tallow effectually preventing the entrance of the fea water into the moft minute cavities. This method is worthy of record, as it may be applied to many other ufeful purpofes. Mr. Rudyerd, as before-mentioned, began his operations in July 1706; in July 1708, he had fo far completed it as to exhibit a temporary light; and the whole was completed in the following year. This building had fome repairs of its timbers in 1723, and again in 1744, when a violent ftorm had carried away a great number of the upright timbers: but it fhewed itfelf, in the courfe of 49 years, to be a very excellent conftruction of its kind, and only liable to deftruction from the perifhable nature of its materials, or the cataftrophe which awaited it on the night of the 2d of Dec. 1755, when one of the attendants, entering the lantern to fnuff the candles, found it in flames, and, notwithftanding every exertion, the fire communicated to the uprights, and burned downwards. The unfortunate men de-

fcended from room to room as the fire increafed, and were at laft obliged to take refuge, from the fall of burning timbers, in a cavity of the rock, from which they were relieved by a boat the next morning. The wind, unfortunately, blew from the eaft, and though it caufed fuch a fwell as to prevent landing, did not break on the houfe fo as to extinguifh the fire; and thus, in a few days, the whole was deftroyed, except the iron cramps in the rock.

It is remarkable, that whilft one of the light keepers, at the commencement of the fire, was looking up at the fire in the cupola of the lantern, a body of melted lead fhowered down upon him, and he declared a quantity had paffed down his throat into his ftomach. He lived only 12 days after being taken on fhore; and on opening the body, a mafs of lead was taken from the ftomach, weighing more than feven ounces. The curious fact, of his having 12 days furvived fo alarming an accident, was communicated by his attendant furgeon, Dr. Spry, to the Royal Society, but the circumftance appeared fo improbable, that it did not, at firft, meet that credit, which future experiments on animals proved he was entitled to.

On the news of the fire reaching London, the proprietors (for by the fale of Capt. Lovel's original leafe, the property of the light-houfe was now in many hands,) immediately took meafures to reftore it, and appointed one of their members, Mr. Rob. Wefton, to the fole management of their affairs, and he being recommended to Mr. John Smeaton, F.R.S., by the prefident of the Royal Society, employed this gentleman to devife the means, and fuperintend the erection, of a new building. Mr. S., whofe originality of genius, and foundnefs of judgment, have fince been fo generally known, was at that time juft entering into his profeffion as a civil engineer, but immediately devoted himfelf to the confideration of the light-houfe, and foon determined upon erecting a ftone building; and reafoned, that by making the building very heavy, and uniting all the ftones firmly together, he fhould obtain fuch a weight and ftrength, as would firmly refift the united action of the wind and water. He determined upon dovetailing the ftones together, as being a more fecure method than cramping with iron, and not liable to interruption from the work getting wetted, as would almoft unavoidably happen in fuch an expofed fituation. On the whole, the building he erected, and which is now ftanding, may be confidered as the moft perfect light-houfe in exiftence, and gives examples of the beft kinds of mafonry. We have therefore given drawings of it in the *Plate* of *Light-houfe*, which are taken from a fuperb work in folio, publifhed by Mr. Smeaton in 1791, entitled "Narrative of the Building, and Defcription of the Conftruction of the Eddyftone Lighthoufe with Stone." It is from the fame fource the whole of this article has been compiled.

Fig. 1. is a fouth elevation of the whole houfe, and *fig*. 2. a fection of the fame. A reprefents the landing place; B a natural cave in the eaft fide of the rock; D an iron rod, ferving as a rail to hold by in paffing up fteps cut in the rock, to the foot of the ladder occafionally put out from the entry door at E. At F is a cafcade of water, pouring over a low part of the rock, but this is only momentary, for the fwell will in an inftant caufe it to fet the other way. In *fig*. 2. *a* B fhews the upright face of the rock, and the line *a b* the general direction of its *grain* or flope. In this figure it is feen that, as high as the firft 14 courfes of ftone work, the building is entirely folid. Here the entry F commences, but excepting this cavity, and the ftaircafe X, the folid ftill continues to the floor of the loweft chamber G, which is the ftore room, and H the door at which the ftores are drawn up and received. I is the upper ftore room; K the kitchen containing the fire-place L, from which the fmoke afcends by a copper funnel *m*, through the bed room M and lantern N, to the ball on the top of the cupola O. The afcent from room to room is by the perforations through the middle of each floor, a moveable ftep ladder being ufed for the attendants; but ftore may be drawn up from the lower room into any other. P is the railing forming the balcony; its floor is covered with very thick fheet lead, turned down over the cornice Q, which furmounts the column of the building. R is the ftone bafement of the lantern, and N the glazed part: the cupola O is fupported by eight caft-iron ftandards, between which the copper window frames are fixed: the ftandards have claws at bottom, which are fcrewed to flat iron bars refting upon the ftone work. By this means the whole lantern is framed together; and to ftrengthen it, the window frames are caft with diagonal bars, as fhewn in *fig*. 2. The whole lantern is held down by eight bolts at its angles, paffing down through the balcony floor; one of thefe is feen at *d*: S is the door to the balcony. The lantern is lighted by 24 candles arranged in two iron circles, one fix feet four inches diameter, containing 16 lights; and the other, three feet four inches diameter, holding eight candles. Thefe circles are fufpended by cords going over pullies, fo that they mutually rife and fall parallel, and counterbalance each other. By this arrangement either circle can be drawn down to fnuff the candles, which is done every half hour, without lofing the whole light. Having thus defcribed the general outline of the building, the minutia of its conftruction comes next to be defcribed, and the manner of uniting the ftones compofing it. The fection, *fig*. 2, fhews the feveral fteps which were cut in the rock to engraft the ftone work upon. *Figs*. 1, 2, 3, &c. denote the different courfes of ftone, each of which makes a level furface with the ftep it is fitted into. The feventh is the firft complete courfe. *Fig*. 3. is a plan of the rock, fhewing the courfes 1, 2, and 3, laid in their places, and exhibiting the dovetails which are cut in each ftep to hold the feveral ftones in their places; and thefe ftones are fo formed as to enlock the others with them in a manner which will prevent any ftone quitting its pofition. The dark fhaded ftones are *moor* ftones, while the lighter forts are Portland ftone. *Fig*. 4. is a plan of the feventh or firft complete courfe, fhewing a central ftone with four dovetails uniting it to four others, and thefe tying in the remainder. All the folid courfes are laid in this manner to the fourteenth, which, as before mentioned, completes the entire folid. Every courfe is laid in fuch a manner upon the one beneath it, that all the joints break each other, as mafons term it, that is, immediately above and below the joints of any courfe the middle of a folid ftone is difpofed. The feveral courfes are retained upon each other, to prevent them fliding fideways, by means of *joggles*, which are plugs or cubes of hard black marble, fhewn by the dark fquares in *fig*. 2, and in the plan, *fig*. 4, to be received one-half through every two adjacent courfes. All the courfes of the entire folids have a central joggle *f*, and eight others, *g*, arranged in a circle round it, as fhewn in *fig* 4. Above the entire folid, the centre ftone is omitted to leave the well-hole for the ftair-cafe, X, or rather, it is compofed of four ftones, united by hook or dovetail joints, to form, when put together, one piece, large enough to have the well-hole through its centre, and the exterior ftones are united to it as a central piece in the fame manner, as *fig*. 4. In thefe courfes the continuity of the ftones being fomewhat broken, double the number of joggles, *h*, and thofe half the fize, are introduced between the courfes. It is to be obferved, that none of the joggles, except the centre ones,

some immediately over the others, as the figure would infer, but they break joint with each other to give every part of the solid an equal strength. Above the solid, a new system of building was necessarily adopted: the lower courses were composed of Portland stones to fill up the centre, and moor stones, as being more durable, to make the outside. The whole of the upper works are of moor stone; and dovetailing being no longer practicable, the stones are united by iron cramps and joggles, as shewn in *fig.* 7, which is a plan of the upper or bed-room M. Each stone is here seen to have an iron cramp to join it to its neighbour, and has a small marble joggle to unite it with that above it. The vertical joints are rendered impervious to water, by cutting a notch between every two adjacent stones, so that when they come together it forms a hole of a lozenge shape, and a piece of stone being put down into this hole with mortar, makes a perfect joint, at the same time increasing the bond of the stones. This kind of joint is partly seen in *fig.* 8, at *n*, but one-half is hid by the iron cramps *r*, *r*, extending over every joint. In this figure they are seen inclined, that they may take firmer hold of the stones *s*, *s*, forming the sides of the apertures T, for the window. The stones of the different floors are dovetailed together, as in *figs.* 5 and 7, and are rather arched on the lower side, as shewn in *fig.* 2. To retain the thrust of these arches, every course from which a floor springs, is bound by an endless chain inlaid in the stone work, as in *fig.* 5, and run in solid with lead. The chain is shewn enlarged in *fig.* 6. *Fig.* 7. is a plan of the bed-room M, shewing the disposition of the three cabin beds *k*, *l*, *m*, with a window between each. The dark spot *m* is the smoke funnel, and *n* is the place for a clock.—The reader is now tolerably well acquainted with the construction of Mr. Smeaton's light-house; but in such a peculiarly exposed situation, every trifling operation was attended with difficulty, and demanded thought and ingenuity to devise the means of accomplishing it. On this account we shall briefly follow Mr. Smeaton through his narrative, though it relates circumstances which, if recorded in the account of a common building, would appear impertinently minute. The season when Mr. Smeaton first took up the business of the light-house not being favourable for a visit to the rock, he did not attempt it till April 1756, before which time he had designed the general principles of the building. He found upon the rock the irons of both the former erections, and several of the moor stones of the late building lying in the gut, which was a narrow channel of twelve feet deep between the house rock, and a reef of rocks to the westward, in which channel the boats coming to the house could lie in fair weather. His first visit was employed in observations on the rock, and in experiments of the time requisite to drill and pick holes of a certain dimension, that he might estimate the time necessary to complete the work on the rock. In succeeding voyages he took dimensions of every part to enable him to make an accurate model, to which he could adapt a model of the intended building. The unfavourable days at sea were employed on shore in examining the stone in the country round, a convenient situation for a work-yard, &c. The dimensions of the rock were taken by the following means: He fixed up the circle of a theodolite, with its index, in the centre of the rock, and levelled it with the spirit-level; a light rod was fixed to the index, long enough, when turned round, to reach all parts of the rock; it was provided with a spirit-level to shew when it stood horizontal. It is obvious that this rod, when turned round, would describe a horizontal plane, and the depth of any point of the rock beneath this plane was ascertained by a rod set up vertically upon the point in question, and applying the horizontal ruler to it. The divisions on the vertical rod shewed the depth; and the division of the horizontal ruler shewed the distance from the centre, and the degrees of the theodolite circle pointed out the direction. By these means the position and altitude of thirty-two principal points were obtained, which were well marked upon the rock, and a line being stretched from one of these points to another, gave the means of determining the position of the iron stanchions, or any thing else which was remarkable. Having thus, in ten voyages, made all the necessary observations on the rock, and determined upon regulations for the management of the work, he returned to London, and, in his way, visited the various stone quarries in Devonshire, and the isles of Portland and Purbeck. He was employed, till the month of July, in making exact models of the building, when he returned to Plymouth, where he found a vessel, the Neptune Buss, which had been fitted up for exhibiting a temporary light during the period of rebuilding the house. From some misunderstanding between the Board of Trinity and the proprietors, this vessel was not employed in this manner, but was devoted to Mr. Smeaton's use, who immediately began the works upon the rock; mooring the Buss near the rock to serve as a retreat for the workmen, who were frequently driven off by the waves. In the month of September the three lower steps of the rock were completed, and the upper ones in a state of great forwardness; after which time, bad weather prevented much more being done that year, and in November the Buss left her moorings to return to Plymouth, in which voyage she was driven to sea, and narrowly escaped shipwreck. Thus concluded the operations of the year 1756. The winter season was passed in preparing stone work on shore, in building boats, and, by Mr. Smeaton, in a long and valuable series of experiments on the different kinds of cements, which could be applied to the building.

In May 1757, the Buss was carried out and moored, and on the 12th of June the lowest and first stone was laid in its place; from the great uncertainty of the weather every stone was so contrived, that it was of itself in a condition to resist the wash of the sea, even when it was immediately laid, and before it was hardened. For this purpose, each stone had one or two holes drilled through it before it left the work-yard, and this hole being continued a few inches into the rock or the stone beneath, a strong trenail, or oaken pin, was driven through it, to pin it fast in its place: as the dovetails did not of course fit perfectly close into each other, but left space for the mortar; notches were cut in the edges of each stone to receive strong oak wedges, which held them firm until the mortar came to its solidity. As a further precaution to defend the mortar, all the outward joints were coated over with plaster of Paris, as a temporary expedient. The work went on rapidly in this manner, and the second course was nearly set in a few days; but a gale sprang up, which obliged them to quit the work, leaving a few stones of the second course, which could not be set, lowered down into their places, and chained strongly to the rock, by lines inserted into the holes made in each of the stones, to lift them by; and one of the most exposed was secured, by laying upon it, when in its dove-tail, a weight of lead of five cwt. in form of a hemisphere. A storm came on, and it was afterwards found, that this weight had been lifted by the waves, so that the stone beneath it had escaped and was lost, as were four others, from which circumstance the force of the sea on the rock may be imagined. New stones were immediately prepared, and the work renewed. In the progress of the work, it constantly happened, after all precautions, that the cement was washed away in particular

places, and it was always repaired the first opportunity with Pozzolana or Dutch terras; which repairs, if they withstood one rough tide, were never found to fail afterwards; but some places were found so difficult, that it became necessary to mix oakum, chopped very small, with the mortar, and this method always succeeded. On the 11th of August the six basement courses were completed, and the first entire course, N° 7, was begun. All the stones for this course were fitted and put together in the work-yard, as shewn in *fig.* 4. They are numbered, so that after being taken to pieces, they could be restored to the same relative position on the building; but to do this accurately, while they were in the work-yard, radial lines were drawn from the centre to the circumference, so as to intersect each stone; and concentric circles were drawn through the middle of each tier of stones. Where any of these lines crossed the joints, a nick was sawn in the edge of the stone, that the mark might be felt as well as seen; and by the coincidence of these lines the stones were set with the greatest accuracy. On the stones arriving at the work, the central stone was first set; the hole to receive the centre joggle was cut through the centre of course six, and the joggle set up therein, as shewn in *fig.* 2, and the centre stone of course seven let down upon it, a mortar bed being made beneath. When the stone was thus fixed, the joints round the joggle were filled in by grouting, which is mortar made very thin and poured in from ladles. The four stones surrounding the centre were now set, and the work proceeded thus to the circumference, every stone being wedged and trenailed as soon as set, and the joints grouted. To fix the eight smaller joggles, they were set, wedged, and grouted into their holes in the lower course; but the holes for their reception in the lower side of the upper course, being only cut half through, did not admit of wedging; they were therefore fixed by the mortar only, as much being put on the top of the joggle as would nearly fill the hole, but not quite, and the remainder was introduced through a hole previously drilled through the stone, and forced down by a wooden ramrod.

The mortar used in the building was compounded of equal portions of lime and pozzolana. The lime was burned from the blue Lyas limestone found near Watchet, a small seaport in Somersetshire. It was carried out in tight casks, which were opened at the rock, and a small quantity beat up in a strong bucket with a wooden pestle, and used immediately. The work proceeded in the same manner without any deviation or accident, except now and then losing a few stones by storms, until the end of September, when the ninth course, being completed, the work was given up for the year, and the Buss left her moorings.

During the winter, the buoy of the moorings for the Buss was lost, but was recovered on the 11th of May, 1758. Yet, before any work could be begun, the chains were broken, and the buoy of the anchors having got loose, the moorings were lost; much time being consumed in preparing new ones, it was the 2d of July before the work was renewed; but by the 8th of August, the 14th course, completing the entire solid, was laid, and by the 20th the entry door was covered in, and by the 24th of September, the whole of the solid, up to the store-room floor, was finished. Above this the method of working was totally altered, but not being now so liable to the action of the sea, it became less difficult, and requires less description. In addition to what has been said before, the iron cramps were all filled in their places with lead, and a whole course was done at once, by putting each cramp into a kettle of red-hot lead, till it was equally hot. A small quantity of oil was poured into the holes in the stone, and the hot cramp put in: this oil caused the lead, when poured in, to occupy every cavity in the stone.

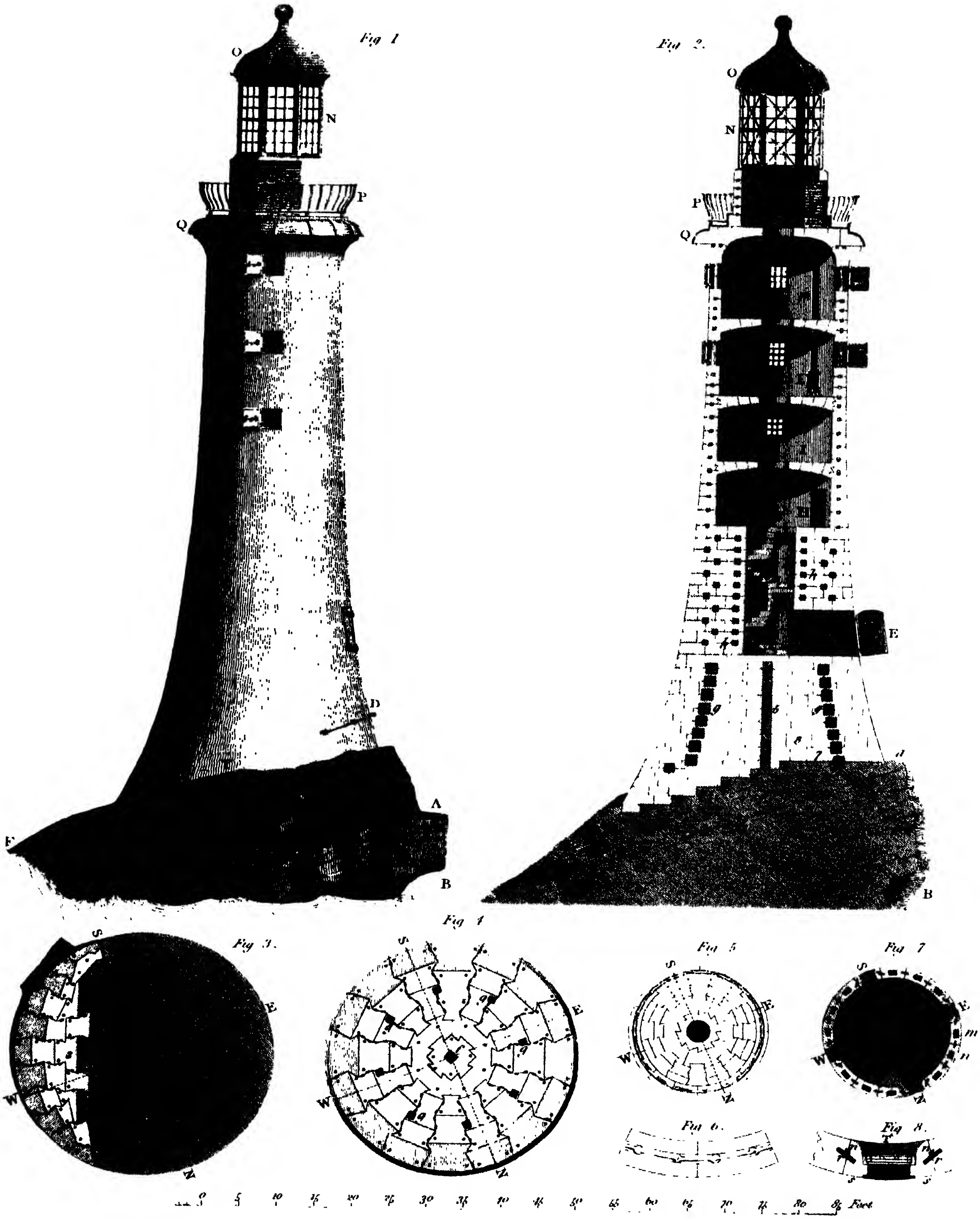
On the 30th of September, the work had arrived at the store-room floor, and here the iron chain, shewn in *fig.* 5, was let into the stone, and filled in with lead in the following manner:—the chain was oiled before putting it in, and the groove divided into four parts by dams of clay. Two kettles were used, which together would hold lead enough to fill the whole groove, which was 11 cwt. In these the lead was made red-hot, and two persons with ladles filled the lead into the same quarter of the groove. As soon as it was at all set, they removed one of the clay dams, and filled the next quarter, pouring the lead on the end of the first quarter, till it re-melted and united with the second. The dam at the opposite end of the first quarter was now removed, and the third filled, and then the 4th. By this means the lead was all round united in one mass.

The centering for the floor was next set up, and the floor partly put together, the outward stones being set first, and then the centre ones. When the first room had been thus finished, Mr. Smeaton proposed exhibiting a temporary light during the winter, and, by fixing three floors in the well for the staircase, to form store rooms, and lodging for two men: but this idea was given up, as it did not meet the approbation of the Trinity corporation, and the work was, on the 7th of October, left for the year, the floor being partly finished. The winter was spent in preparing the iron, glass, and copper work for the lantern; and the spring in unsuccessful endeavours to recover the moorings which were again lost, and on the 5th of July the work was begun again. They found one of the stones for the floor, which was lodged in the store room H the year before, had been washed down the well, and thence through the entry into the sea, though it weighed four or five cwt. The stones for the building had hitherto been raised out of the boats, by what are termed *shears*, formed of two poles, united at top, and their feet pitched on the rock close to the building, at a proper distance asunder. A block of pullies was suspended from the top of the two beams, to take up the stone. The shears were supported by a tackle called a guys, which was attached to the top of the shears, and hooked to the far side of the building, so that the stone, being raised up from the boat by a windlass fixed on the rock at Y, *fig.* 1, the guy was drawn in to swing the stone over the building. When the work got above the entry E, the stones were landed into it, and drawn up the well X by a tackle suspended from a small triangle set over the well; but when the floor was covered in, the hole in the centre being too small to let the stones come up, a smaller pair of shears were made to lie upon the building and rise as it advanced. These were worked by a windlass set up in the store room H, and as they hung over the sides of the building, they drew up the stones clear of the wall. The work proceeded in this manner till the 17th of August, when the last piece of the cornice Q was fixed, which completed the whole column, and the workmen were enabled to lodge in the building. The balcony rails P, and the stone basement R of the lantern, were soon completed; and by the 26th, the stairs and all the masonry were finished. The iron frame of the lantern was next screwed together in its place, all the joints being first smeared with thick white lead and oil to prevent them from rusting: it was then raised up on wedges a small height, and lead poured in the joint between it and the stone to make a solid bed for it upon the stone. On the 17th of September, the copper cupola O was set up, by a particular kind of shears made for the purpose, the guys, in different directions, being fastened to booms projected out from

the ſeveral windows of the upper room. The next day the ball, which was double gilt, was ſcrewed on; and by October the 16th, an electrical conductor was fixed, which finiſhed the edifice. A light was then exhibited, which has been continued ever ſince without any particular occurrence, or any accident produced by the many violent ſtorms which have happened ſince. Mr. Smeaton has, in the title page of his narrative, given a repreſentation of the houſe in a ſtorm, as ſeen through a teleſcope from Plymouth, when the waves daſh up againſt the building, till they meet the cornice Q, by which the water is thrown off in all directions in a white column, which envelopes the houſe like a ſheet, and riſes to at leaſt double its height, though the top of the ball is 100 feet above low water. See BEACONS.

LIGHT HOUSE.

LIGHT HOUSE on the Eddystone Rock.



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Lignite

LIGNITE. This name is given, by Brongniart, to the species of inflammable fossils, called *braun kohle* (brown coal) by Werner. The following account, from Brongniart's Traité de Minéralogie, will supply the omission of the article *Brown coal* in our work.

Lignites vary in colour from deep and shining black to a dull earthy-brown: the texture of most of the varieties indicates their origin and explains their name. The ligneous texture is often observable, though sometimes it has wholly disappeared. Its fracture is compact, often resinous and conchoidal, or shining and even.

The combustible minerals belonging to this species are characterised by their smell and the products of their combustion. The odour which they emit in burning is pungent, often fetid, and has no analogy with that of coal or bitumens. They burn with a pretty clear flame, without bubbling and caking, like coal, and becoming fluid in the manner of the solid bitumens; they leave powdery ashes similar to those of wood, but often more abundant, more ferruginous, and more earthy. The ashes contain a small portion of potash; at least Mr. Majon has found about 3 in 100 in those of the bituminous wood of Castelnuovo. These combustibles yield an acid by distillation, which coal does not.

The external characters of the varieties of this species vary too much to allow them to be farther generalised.

1. *Jet Lignite; Jayet. Pech kohle*, Wern.

This substance is hard, solid, compact, and susceptible of a bright polish; it is opaque and of a pure black colour; its fracture is undulated, and sometimes shining like that of pitch. Specific gravity 1.259. It is said to be sometimes lighter than water; but Brongniart thinks this property rather belongs to the following variety.

Is found in strata of little thickness, in marly, slaty, calcareous or gritty beds. It sometimes exhibits the organical texture of wood.

It is found in France; in Provence, at Belestat in the Pyrenees; in the department of the Aude, near the village des Bains, six leagues to the south of Carcassone (this sometimes contains amber), and near Quilhan, in the same department, in the communes of Sainte Colombe, Peyrat, and Bastide; it is situated at the depth of ten or twelve yards, in oblique strata between strata of sand-stone; but these strata are neither pure nor continuous. Jet proper to be worked is found in masses, the weight of which is seldom 55 pounds. These mines have been wrought for a long time, and have produced a considerable quantity of jet, which was cut and polished in the same country. It also occurs in Germany, near Wittemberg in Saxony, where it is also cut and polished. Very fine jet has also been found in Spain, in Galicia, and the Asturias. Is likewise said to occur in Iceland, in the western part of the island.

Besides these, professor Jameson has quoted the following localities of pitch-coal or jet lignite: the coal districts of the

Lothians, Fifeshire, Linlithgowshire, island of Skye, and Cannoby and Sanquhar, in Dumfriesshire, in Scotland; Newcastle, Tindel fells, Bolton and Whitehaven, in England; Austria; Hungary, Bannat, Transylvania; Upper Lusatia; Silesia; mount Meissner in Hessia; Würtenberg; Franconia; Bavaria; Salzburg; Italy; Prussia.

Of this combustible ornaments are made, particularly mourning trinkets; it is polished with water on a horizontal wheel of sand-stone. Jet mixed with pyrites is generally rejected.

2. *Friable Lignite; Moor coal; Moor kohle,* Wern.

This variety occurs in thick and extensive beds. It is of a lively black, but less shining than that of the preceding variety. Its great friability is particularly characteristic of it. Its surface is always cracked, and its masses divide with the greatest facility into a number of cubic fragments; a character which is not found in jet.

Friable lignite is more abundant and consequently more useful than the two first varieties. It is found in horizontal banks often thick and extensive, but is never seen in such large masses as coal, with which it has been confounded by some; it differs not only by its properties but also by its geognostic situation. It occurs in those masses of sand which often fill up vallies in calcareous mountains, or cover the sides of the hills that skirt them. Is also found, though more rarely, in clayey marle.

Friable lignite is pretty common in the south of France, such as in the department of Vaucluse. Also as considerable mass at Luette, department des Forêts.

Other localities cited by authors are Leitmeritz, Saatz, and Ellenbogen in Bohemia: Thalern near Krems in Austria; Transylvania; Moravia; the island of Bornholm in the Baltic, and the Faroe islands. It occurs more frequently in Bohemia than in any other country. Jam.

It burns without difficulty, but spreads a very disagreeable odour. It can be made use of only in manufactures, or to burn lime. Smiths cannot use it in their forges.

3. *Fibrous Lignite; Bituminous wood; Bituminöses holtz,* Wern.

Its colour varies from a clear blackish-brown to clove brown; it has a perfectly woody form and texture; consequently, its longitudinal fracture is fibrous, and its transversal fracture shews the yearly layers of the wood. It is more easily frangible than wood, and takes a degree of polish when cut with a knife.

This lignite often occurs in large masses.

It is found in France; in the vicinity of Paris, near St. Germain, in the isle of Chatou, which appears to be entirely formed of it; and near Vitry on the banks of the Seine, where is a thick bed of trunks of trees well preserved. In the department of Arriège, the clefts of this lignite are filled with calcareous spar. In Liguria, near Castelnuovo, at the mouth of the Magra, it is found in thick and extensive beds. In Hessia, in the mountains of Ahlberg, the stratum is above two yards thick. At Steinberg, near Münden in Hanover, it forms two strata, one of about ten yards, the other of six, separated by a bed of rock from twelve to fourteen inches thick. In England, at Bovey near Exeter, there are seventeen pretty thick strata, situated at a depth of about twenty-two yards under sand and in potters' clay. In Iceland, where it is very abundant, it is called *Surturbrand;* the trunks which form these beds are very distinct, and appear merely to have been compressed.

To these localities we add the following from Jameson: Scotland, in the fletz-trap formation, accompanied with pitch-coal, in the island of Skye; in separate pieces in trapp-breccia in the island of Cannay; in fletz lime-stone, in the island of Skye, and in the independent coal formation in the county of Mid Lothian; Bohemia, in the Saatz and Leitmeritz circles; Austria; Transylvania; Moravia; Leoban in Stiria; Irsenberg in Bavaria; Upper Palatinate; Landeck in Silesia; Halle; Merseburg; Artern and Eisleben in Thuringia; Kalten-Nordheim near Eisenach; Wehrau, Upper Lusatia; Würtenberg; Freeienwalde and Königswalde in Brandenburg; Westerwald; Salzburg; Russia.

But this lignite is still more common in small detached masses; it sometimes accompanies the preceding varieties; sometimes it is found alone in small layers, in the midst of banks of clay or sand. It is met with almost every where, and is used as fuel in those places where it is abundant.

This combustible being scarcely decomposed, and hence rather vegetable than mineral, would not deserve to constitute a variety in a system of mineralogy, if it did not pass by imperceptible degrees into the preceding varieties, and into that which follows.

4. *Earthy Lignite; Earth coal; Erd kohle,* Wern.

Commonly called earth of Cologne, and sometimes, though improperly, *umber;* but the true umber, which comes from Italy or the east, contains nothing that is combustible, whence it cannot belong to this species.

This substance is black, or blackish-brown mixed with reddish. Its fracture and aspect are earthy; it is fine-grained, easily frangible and even friable; it is rather soft to the feel. Its specific gravity is nearly that of water. It burns, emitting a disagreeable smell.

It not only often contains vegetable remains, but sometimes itself presents the texture of wood, without ever possessing either the colour and lustre, or the hardness of the preceding varieties. It burns sufficiently well to be used as fuel. It gives a gentle and equal heat.

It is found in secondary formation in the neighbourhood of coal mines, and more frequently in alluvial land.

As an authentic example of this variety may be mentioned the earthy lignite from the vicinity of Cologne, known in trade by the name of earth of Cologne. It is dug up at a little distance from that city, near the villages Brühl and Liblar, where it forms very extensive beds of eight or ten yards in thickness, which are situated under elevated ground. It is immediately covered with a bed, more or less thick, of rolled pieces of quartz and jasper, of the size of an egg, and rests on a bed of white clay of an unknown thickness. The bed of lignite is homogeneous, but fossil vegetables are found in it in a good state of preservation; they are, 1, trunks of trees lying one on the other without order; the wood is black or reddish, generally compressed; it readily exfoliates by drying in the open air. Some of these belong to dicotyledonous trees, others are fragments of palms. Among these M. Coquebert-Montbret has found some that are filled with a number of small round pyritic bodies resembling grains of small shot. Similar small, but elongated round grains, resembling a two-celled pod, have been found by Mr. Heim, in the lignite of Kalten-Nordheim. This wood burns very well, and even with a small flame. 2. Woody fruits, of the size of a nut, and which are considered as belonging to a species of areca. The lignite of Cologne contains about twenty *per cent.* of ashes rather alkaline and ferruginous. Its uses are manifold; it is worked in open air with a simple spade, but in order to convey it with greater convenience, it is moistened and moulded in vessels which give it the shape of a truncated cone. It is generally used as fuel in the neighbourhood of Cologne. It burns slowly but readily and without flame, like fungus-tinder, giving a strong heat and leaving very fine ashes. The latter being considered as a very good manure, a part

of the lignite is burnt on the ſpot where it is wrought, for the ſake of obtaining them.

The earth of Cologne is particularly employed for painting in diſtemper and even in oil painting. The Dutch uſe it to adulterate ſnuff, and if it is not added in too great a quantity it gives the ſnuff a deſirable fineneſs and ſoftneſs, and cannot be in the leaſt injurious. Faujas.

This lignite is ſaid to occur alſo in Heſſia, Bohemia, Saxony, Iceland, &c.; but as there has been a confuſion between this ſubſtance and the variety of ochre called *umber*, we cannot be certain that theſe indications of localities are referable to earthy lignite.

It may have been obſerved, from what has been ſaid on the ſituations peculiar to ſome varieties of lignite, that this foſſil combuſtible belongs to depoſitions of the moſt recent formation, ſince it is found only in alluvial ſand or clay; it ſeldom or never occurs in ſtony depoſitions, except in coarſe grained lime-ſtone and under baſalt. In the mountains of Heſſia called the Ringe Kuhle, ſeveral thick beds of lignite are ſeen reſting on ſandſtone, and ſeparated by beds of potters' clay and ſand.—(Mohs). On the ſea-ſhore near Calais, fragments of lignite have been found that were penetrated by very tranſparent globularly aggregated quartz cryſtals.

The air which circulates where lignite is wrought is generally bad.

From what has been ſaid it appears (our author concludes) that lignite is of a very different formation from that of coal; indeed, Mr. Voigt thinks that there is no tranſition between theſe two ſubſtances.

The firſt of Brongniart's varieties of lignite, is by Werner given as a ſub-ſpecies of his ſchwartz kohle, or black coal.

A variety not mentioned in the above account of lignite, but nearly related to the fibrous lignite No. 3, is the ſub-ſpecies of Werner's brown-coal, called *common brown-coal*. Its colour is light browniſh-black, paſſing into blackiſh-brown. It occurs maſſive. Its fragments are indeterminately angular, more or leſs ſharp-edged. It is found at Bovey, and ſeveral other places mentioned under the localities of fibrous lignite or bituminous wood.

Lime

Lime, *Burning*, a term ſignifying the proceſs of converting lime-ſtone, chalk, marble, ſhells, and other calcareous ſubſtances into lime, by means of heat, in kilns properly conſtructed for the purpoſe. See Kiln.

In theſe caſes, the calcination is effected by different ſorts of fuel, in different ſituations, but principally by foſſil-coal, peats, or woods; theſe being laid in layers, alternately with thoſe of the calcareous materials, in the kilns, and the proceſs of burning continued for any length of time, by repeated applications of fuel and calcareous matters at the top, and drawing out the lime from below occaſionally as it is burnt.

But mineral coal, or culm, are unqueſtionably the moſt convenient and ſuitable materials for effecting this buſineſs, where they can be procured in plenty, and at a ſufficiently cheap rate, as they burn the ſtone, or other calcareous matter more perfectly, and, of courſe, leave fewer cores in the calcined pieces than when other ſorts of fuel are employed for the purpoſe.

However, Mr. Dodgſon has had much ſucceſs in burning lime by the uſe of peats; as he ſtates, in the Farmer's Magazine, that he is "convinced, from experience, that lime-ſtone can be burnt to better purpoſe, and at leſs expence, with peat than with coal. When coal is uſed, the lime-ſtones are apt, from exceſſive heat, to run into a ſolid lump, which never happens with peat, as it keeps them in an open ſtate, and admits the air freely. The proceſs of burning, alſo, goes on more ſlowly with coal. No lime can be drawn for two or three days; whereas, with peat, it may be drawn within twelve hours after fire is put to the kiln; and in every ſucceeding day nearly double the quantity of what could be produced by the uſe of coal. The expence is comparatively ſmall. A man and a boy will dig as many peats in one day as will burn 60 Carliſle buſhels of lime, (the Carliſle buſhel is equal to three Wincheſter ones,) and the expence, including drying, will not exceed four, or, at moſt, five ſhillings; while the coal neceſſary for burning the ſame quantity of lime would have coſt twelve ſhillings at the pit. The wetneſs of ſeaſons is no argument againſt the uſe of peats, as they can be ſtacked near the kiln, when half dry, at any time of ſummer; the moiſture will be exhaled from them during winter, and they will be in a fit ſtate for burning in the months of April or May. He lives in the north-eaſtern diſtrict of Cumberland, where the farmers, in general, burn their own lime; and though there is coal in the immediate neighbourhood, he gives a decided preference to peat, for the reaſons above-mentioned." And it is well known, that this kind of fuel has been occaſionally uſed in many parts of the kingdom for the ſame purpoſe, from a very early period, without any complaint of the want of ſucceſs.

In the practice here ſtated, no particular form of kiln was found neceſſary, nor any particular ſort of management in the proceſs of calcination; the proportion of peat depending upon the nature of the lime-ſtone employed, and other circumſtances.

It has been conſidered by Mr. Marſhall, that "the manufacture of lime is an art of which the manager of an eſtate ought not to be ignorant." And he conceives, that "he ought to have, at leaſt, a ſufficient knowledge of its theory, to enable him, when occaſion requires, to ſuperintend or direct its practice. For it ſeldom anſwers, unleſs where materials are plentiful and fuel cheap, for every tenant upon an eſtate to manufacture his own lime. A full-ſized kiln accumulates a ſtronger heat, with a given proportion of fuel, than a ſmall one of the ſame form," which is without doubt a great ſaving.

It is ſuppoſed, that "the chief or ſole intention of burning lime-ſtone for manure, appears to be that of reducing it in the readieſt and cheapeſt manner to an impalpable powder. For experience ſufficiently ſhews, that quick lime is injurious, rather than beneficial, to vegetation; and that burnt lime-ſtone does not operate as a manure until it has regained the fixed air, of which the fire deprived it. If it could be reduced by mechanic powers to powder of equal fineneſs, its effect, as manure, would doubtleſsly be the ſame as that of dead lime (effete). It is in the perfect ſolution which well-burnt lime-ſtone has received, by the expulſion of its fixed air in the fire, ſo as to have completely looſened its texture, and unbound its every atom, that we are to look for its prompt effect and the ſhortneſs of its duration, comparatively with unburnt calcareous ſubſtances. Hence

the main point to be attended to is to expel the whole of the air. For, unlefs this be accomplifhed, the folution becomes imperfect; the ftones, inftead of completely diffolving into impalpable atoms, break into granules, or flakes; leaving, perhaps, a firm core in the centre, to encumber, rather than to fertilize, the foil" on which they are applied. "There is, however, an oppofite extreme to be avoided, and with greater care. For an unburnt ftone may be returned to the kiln, but one which, by too intenfe a heat, is vitrified, or changed to a ftate of impure glafs, is not only rendered ufelefs, but has incurred an extraordinary wafte of fuel. Confequently, ftones that are prone to vitrification ought to be broken down into fmall pieces; otherwife, the fire is required to be fo intenfe, that the furface becomes vitrified, before the air from the centre can be expelled." And "another fuggeftion, refpecting the proper fize of the ftones to be burnt, may have its ufe. Where fuel is weak, or dear, the materials require to be broken into fmaller fragments, than where a ftrong fire can be kept up at a fmall expence; while, under the latter circumftance, and where the ftone is not prone to vitrification, much of the labour and expence of breaking may be faved, by ufing an extra quantity of fuel, and keeping up a ftrong fire in the kiln," or place where it is burned; the form or conftruction of which depends partly on the qualities and value of the materials, and partly on the kinds of fuel that are made ufe of, and the differences of their prices at the places where they are employed. See KILN.

It is ufeful that the procefs of burning lime fhould go on during January and February, as well as moft of the winter, and alfo in the fummer months. Perpetual kilns are wrought in many diftricts, efpecially the northern ones, and in Ireland; the lime, when not taken away, being preferved, in fheds erected for the purpofe, from the wet. The ufual mode of managing with them is, for the farmers to contract for fome fort of meafure, according to the cuftom or practice of the particular diftrict; being careful that it is well burnt, and of a proper quality in other refpects. The differences in the expence of burning will depend on the abundance or fcarcity of fuel, and the convenience of the ftone for carriage.

Liverpool

LIVERPOOL, a market town, borough, and fea-port, in the county palatine of Lancafter, England. It is placed on the eaftern bank of the river Merfey, which flows into the Irifh fea, not far north of Liverpool. The population of this town, according to the parliamentary returns of 1800, amounted to 77,653 perfons, who occupied 11,446 houfes.

The etymology of the word Liverpool is much involved in obfcurity, though many ingenious antiquaries have endeavoured to afcertain it. The moft general opinion is, that it owes its origin to a fpecies of bird called the *lever*, great flocks of which are faid to have frequented a pool in this neighbourhood, during their wanderings from their native climes. Accordingly a bird has, from time immemorial, been the impreffion on the corporation feal. The early hiftory of this town is equally as unknown as the derivation of its name. Fortunately, however, the deficiency of records concerning it cannot be felt as a great lofs, as there feems little reafon to fuppofe it was of any importance, either commercially or politically, previous to the commencement of the laft century; hence it may be called a modern town.

" Yet fcarce an hundred annual rounds have run,
Since firft the fabric of this power begun;
His noble waves inglorious, Merfey roll'd,
Nor felt his waves by labouring art control'd.
Along his fides a few fmall cots were fpread,
His finny brood their humble tenants fed."

Mount-Pleafant, a poem by Rofcoe.

To the active, perfevering, and liberal conduct of the author of thefe lines, Liverpool is materially indebted for its prefent increafe of buildings, commerce, &c. and it would have reflected credit on the free burgeffes of the town, had they continued to elect him their member.

In the Conqueror's furvey, it is ftated, that all the land between the rivers Ribble and Merfey belonged to Roger de Poictiers; but there is no mention either of a town or village. Hence it may be reafonably fuppofed none exifted at this time. A caftle, however, is noticed by Camden, as having been built fhortly after the conqueft, the command of which was beftowed on Vivian de Molyneaux, a Frenchman, in whofe family it continued till the 30th year of the reign of queen Elizabeth.

Neither hiftory nor tradition determine any thing certain, either concerning its founder or the period of its erection.

The tower, which forms part of a prifon in Water-ftreet, is the only building of antiquity which Liverpool can now boaft of poffeffing. The original founder of this tower we are as ignorant of as we are of the founder of the caftle. Seacombe, in his Memoirs of the Stanley family, is the firft author who mentions it. He tells us, that it was the property of fir Thomas Latham, in the reign of Edward III., whofe daughter and heirefs married fir John Stanley; but fays nothing of its erection. The crofs which formerly ftood at the corner of Pinfold lane, oppofite the Flafhes, has been long demolifhed. This tradition reports to have been placed there in commemoration of St. Patrick, who, it is faid, refted in this neighbourhood on his way from England to Ireland.

The firft charter in favour of Liverpool, according to Enfield, who publifhed a hiftory of Liverpool, was executed in the reign of Henry I., but the accuracy of this ftatement is extremely doubtful. It is certain, however, that in the charter granted by king John in 1203, nearly a century afterwards, this town is called a borough by prefcription. Henry III. confirmed the privileges of the corporation in the year 1227. From this period to 1555, we are totally in the dark as to its hiftory or condition; nor is there any thing worth remarking for the 16 years following, when the inhabitants fent a memorial to queen Elizabeth, praying relief from a fubfidy which her minifters had impofed upon them. In this petition they ftyle themfelves "her majefty's poor decayed town of Liverpool." How the town became fo "decayed," it is now difficult to comprehend, as, from the records feveral years previous, it does not feem to have been any better than a fifhing hamlet, containing about 138 houfeholders and cottagers, and poffeffing 12 barks, navigated by 75 men. Camden, however, who wrote in 1586, confidered it in his time as more famous for its beauty and populoufnefs than for its antiquities. To reconcile thefe oppofite ftatements, it is only neceffary to admit, that a very trifling village may arrive at confiderable opulence in the fhort period of 21 years; and who will deny the poffibility of fuch an event at the prefent day? From Camden's time nothing is recorded of Liverpool deferving of notice till the year 1644; when the town and its caftle were poffeffed by the parliamentary troops, under colonel Moore. It was fortified and fecured on the land fide by a high mud wall, and a ditch twelve yards wide and three deep. Batteries were erected at different points, and the ends of the ftreets were defended by artillery. The garrifon was numerous, and being well ftored with provifions, made a moft vigorous defence for the fpace of a month. At laft, however, the king's army, under the orders of prince Rupert, fucceeded in taking the town, when the caftle furrendered without further refiftance. Some traces of this fiege can yet be difcovered at different points. When the foundation of the prefent infirmary was funk, the marks of trenches were diftinctly vifible, and many articles of modern warfare were found within their fcope. A few years ago, as fome workmen were removing the earth in a field where Gloucefter-ftreet now ftands, they laid open the foundation of a battery, and difcovered military utenfils of different kinds. From the time of the fiege till 1680, we have a tolerable account of the progrefs of the town in extent and population. After this period, however, we are again left in obfcurity, and receive no authentic information on that head till the year 1765, when we find a plan of the town made by Mr. John Eyes. About this time, fays Enfield, Liverpool contained about 4200 houfes, and 25,000 inhabitants. It had, in the interval laft-mentioned, been conftituted a diftinct parifh from that of Walton, to which its church had formerly been only a dependent chapel. This event took place in 1698, when the inhabitants were likewife authorifed to build a fecond church. Thus emancipated from parochial fubferviency, Liverpool began to difplay its energies. In the fhort fpace of little more than half a century, this town, aided by a few favourable circumftances, has rifen to great commercial importance, and may be confidered to be next to the metropolis itfelf. She firft rivalled, and latterly furpaffed, Briftol, which had long been confidered as the weftern emporium of trade.

The following table exhibits the progreffive increafe of the dock duties for feveral years, and ferves to difplay the vaft and rapid increafe of the commerce of the town. It fhews the number of veffels that have been affeffed in each year, with the aggregate fum paid to the dock companies.

Years.	*Ships.*	*£.*	*s.*	*d.*
1760	1245	2,330	6	7
1765	1930	3,455	8	4
1770	2.73	4,142	17	2
1775	2291	5,384	4	9
1780	2261	3,528	7	9
1785	3429	8,411	5	3
1790	4223	10,037	6	2
1795	3948	19,368	16	4
1800	4746	23,337	13	6
1802	4781	28,192	9	10
1805	4618	33,364	13	1
1807	5791	62,831	5	10
1809	6023	97,580	19	3

The boundaries of Liverpool extend confiderably beyond the town in different directions. Thefe are marked out by ftones called by the inhabitants meer-ftones, and the ground contained within them is denominated the liberties. The extent of the liberties from eaft to weft, is fomewhat more than a mile and two furlongs, and from north to fouth confiderably above two miles. This town exhibits, in general, the appearance of opulence and refinement. The ftreets are well paved, and during winter tolerably furnifhed with lamps. Of late years it has received many great alterations and improvements, which ftill continue to proceed notwithftanding the preffure of the times. In the year 1790, it confifted of 8865 houfes, but their number now is little fhort of 13,000.

Liverpool poffeffes fifteen churches belonging to the eftablifhment, fome of which are worthy the particular attention of the ftranger. Near the old church, which is dedicated to our Lady and St. Nicholas, there formerly ftood an image of the latter, to which the failors were accuftomed to make offerings on going to fea. This church has been lately rebuilt. The tower of St. Peter's, which was erected in 1704, is a well-proportioned octagon, each fide of the angles having a candleftick and gilt vafe reprefenting a flame. This and St. Nicholas are the parifh churches, and have two rectors over them. The church of St. George, built on the fcite of the ancient caftle already mentioned, is a fine edifice of the Doric order, crowned with an attic wall, and adorned with a variety of vafes. On each fide is a terrace with receffes underneath. The interior is handfomely fitted up, the fronts of the galleries being mahogany. This is the mayor's chapel, where he attends every Sunday, and where pews are appropriated for the gentlemen, including ftrangers, who choofe to accompany him. St. Thomas's church is of the Ionic order, and has a handfome appearance. It was confecrated in 1750. St. Paul's church was erected by the town in 1769. At the weft end is a portico with a pediment, having in the centre, on an octagonal bafe, a dome

with a lanthorn, ball, and crofs. The interior is fupported by eight Ionic pillars. The altar is plain and neat. The church dedicated to St. Ann, on the road to Everton, is a neat building of brick and ftone. It was erected at the joint expence of two private gentlemen. It has a tower decorated with pinnacles. St. John's church is a new building of ftone, with a tower. St. Mary's and the other churches have nothing connected with their ftructures or appearances deferving of particular notice; though all of them are entitled to be called neat. Befides the places of worfhip belonging to the eftablifhment, there are a great number of diffenting meeting houfes, or chapels, for various defcriptions of religionifts.

The public edifices connected with the trade and commerce of the town are, the exchange Buildings, town-hall and manfion houfe, cuftom-houfe, corn exchange, tobacco warehoufe, and other warehoufes. Of thefe the Liverpool exchange is the moft fpacious in plan, and ornamental in its exterior architecture. It has been erected by a fubfcription of 80,000*l.* raifed by 800 transferable fhares. The buildings occupy three fides of a quadrangle, having the town-hall on the fouth fide. The whole furrounds an area of 194 feet by 180. It has been built by John Forfter, efq. (architect, engineer, and dock mafter to the corporation) from defigns by James Wyatt, efq. architect; and is appropriated to a public exchange rooms, coffee rooms, and various offices. The town-hall, formerly called the exchange, is a large infulated pile of building, the greater part of which was erected in 1750, from the defigns of Wood of Bath. The whole of its interior was burnt in 1795. It was foon repaired, and appropriated to the ufe of the mayor, for offices belonging to the corporation, feffions rooms, &c.

The infirmary is another excellent building of brick ornamented with ftone. This eftablifhment not only extends to all proper objects within Liverpool, but to every perfon whom ficknefs or bodily misfortune may lead to apply, provided they are recommended by a fubfcriber. The feamen's hofpital forms a portion of the buildings of this infirmary, being attached to it by a handfome colonnade. The bluecoat hofpital is placed in an airy fituation adjoining to St. Peter's church-yard. It is a large handfome building of brick ornamented with ftone. The number of perfons who annually receive the benefits of this charity are about 280. The expence of this inftitution is defrayed chiefly by benefactions.

The poor-houfe is a handfome edifice, 90 feet long and 24 broad, built in a plain ftyle, and in a manner very fuitable to its ufe. On the eaft fide of this ftructure is a handfome ftone building, called the "recovery ward," where perfons infected with fevers, and coming under the cognizance of phyficians and furgeons of the difpenfary, are received. A variety of alms-houfes range out on both fides of the poor-houfe. In Church-ftreet is the difpenfary, which is a very good brick building, with a large circular portico, and having in front a fmall bas-relief of the good Samaritan. This inftitution is conducted by a prefident, two auditors, feven phyficians, three furgeons, and one apothecary, who officiates as fecretary. Two phyficians and a furgeon attend every day at certain hours. About 10,000 perfons are faid to receive medicine and advice here annually. The Lunatic-afylum is contiguous to the infirmary, but, like moft other inftitutions of the kind, cannot be called a complete charity, as patients are not admitted free of expence. At the entrance into the town, on the road leading from Prefcot, ftands the fchool of induftry for the indigent blind. The original projector was Mr. John Chriftie, who was himfelf unfortunately deprived of his fight at the age of 19. In this fchool pupils are taught various trades, which enable many of them to make a comfortable provifion for life. Befides thefe charitable inftitutions there are a number of others, under different names, intended for the relief of different defcriptions of perfons, which the limits of an article like this will not permit us to mention particularly.

Liverpool abounds, as may be fuppofed from its great trade, with rooms appropriated for public correfpondence, and the tranfacting of bufinefs. The Atheneum, which comprifes a news-room, a library, &c. is fituated on the fouth fide of Church-ftreet, and is a handfome building of ftone. The fubfcribers to this inftitution, about 450 in number, are fupplied with the London and provincial newfpapers, the fhipping and trade lifts, and various periodical publications. Every fubfcriber is allowed the privilege of introducing his friend, provided he be a non-refident of the town. There alfo feveral more inftitutions of a fimilar kind in different parts of the town. Of thefe, the Lyceum is the firft and moft worthy of attention. It is fituated at the bottom of Bold-ftreet, and is another remarkable inftance of the munificence and public fpirit of Liverpool. An academy, for the encouragement of the fine arts, has recently been eftablifhed in this town. The places of public amufement are now little inferior to thofe in the metropolis. The theatre is a fpacious and commodious building, and but little inferior to that of Covent-garden in the extent of its ftage. It generally opens at the time the London houfes fhut; when many of the firft performers refort to it. In Bold-ftreet ftands the Mufic-hall, which was opened in 1785. It is a large building, finifhed with great elegance. The new prifon, according to the Howardian plan for folitary confinement, is on a very extenfive fcale, and has every poffible convenience.

Liverpool abounds in docks for the fafety and repair of its numerous fhipping. The firft dock was conftructed here in 1710. Its fcite was the pool, from which the town derived the latter portion of its name. This bafon of water is called the old dock, and is principally the receptacle of Weft India and African fhips, being contiguous to the warehoufes of the merchants engaged in thofe branches of commerce. The King's dock is 290 yards in length, and 90 wide. On the eaft fide of this dock ftands the tobacco warehoufe, where that article is lodged by the cuftom-houfe officers till the duties are paid. It was erected by the corporation, and is rented by government at 500*l.* *per annum.* St. George's dock was the third made in Liverpool. It is about 250 yards long, and 100 broad; and is efteemed commodious. The largeft, laft conftructed, and beft finifhed however of the Liverpool docks, is the Queen's dock, which is fituated at the bottom of Parliament-ftreet. Salthoufe dock, which is the fecond oldeft of the whole, comprifes an area of 21,928 fquare yards; and has a length of quay of 640 yards. Befides thefe there are five graving docks, and three dry docks, independent of a fmall one, which belongs to the earl of Bridgewater, for the ufe of the canal flats. Some of thefe docks communicate, fo that fhips can pafs from one to the other, and into the graving docks, without being obliged to go into the river. All the wet docks are likewife connected by large tunnels, for the purpofe of one dock cleanfing or wafhing another. When large fhips loaded arrive at neap tides they are compelled to remain in the river till the flow of the fpring tides, as the dock gates have not depth of water fufficient to admit them. This circumftance is certainly a great inconvenience, but it is amply compenfated by the capacioufnefs and excellent arrangement of the docks themfelves.

The cuftom-houfe is fituated at the eaft end of the old dock. It is built of brick, in rather a neat ftyle. A fmall flight of fteps leads to a piazza, over which is the long room, and behind it are extenfive warehoufes. At the fouth end of the town is St. James's walk, from which the fpectator has a fine view of the town, the harbour, the river, the fea, and the Welfh mountains. Behind this lies an excellent quarry, the entrance of which is by a fubterraneous paffage, fupported by arches. Bootle-fprings, about four miles diftant from Liverpool, fupply the town with water, which is conveyed by means of pipes.

The principal manufactures are thofe of china and earthen ware, the feveral branches of the watch making, and extenfive falt, iron, and copperas works. It is computed that about 3000 fhipwrights are conftantly employed in the different dock-yards of this town. The river, which is here about 1200 yards broad, abounds with falmon, cod, flounders, and turbot. Ships of any burden may come up to this town with perfect fafety, even at the loweft tides. The accommodations for fea-bathing have, of late years, received vaft improvements, and are not perhaps inferior to any in the kingdom.

Liverpool undoubtedly owes all her opulence and grandeur to the fpirit and enterprife of her merchants. She exhibits, to the eye of the ftatefman and philofopher, a diftinguifhed inftance of the rapid progrefs of commercial greatnefs. A century ago, a few coafting veffels and petty traders formed the whole of her wealth. For the firft fifty years her advance was comparatively flow. After this period, however, the increafe of trade which fhe every year acquires, is truly aftonifhing. She fhares a portion of the commerce of almoft every country in the world. Of late years, Liverpool has confiderably decreafed, in common with that of all the other towns in the kingdom. What effect the abolition of the flave-trade may ultimately have upon Liverpool, it is not poffible to prognofticate. For the prefent, however, the mercantile houfes, formerly engaged in that traffic, muft undoubtedly fuffer confiderable difficulties before they can turn their capital and attention to fome object more honourable than the purchafe and fale of human beings.

Independent of the advantages Liverpool poffeffes for foreign commerce, it has communication with all the interior counties by canals. Thefe again, being joined by others at different points, extend themfelves to the Severn, to the Humber, and to the Thames; thus connecting the four principal trading ports in England. To the beneficial effects of thefe canals Liverpool has to attribute much of her prefent greatnefs.

The markets of Liverpool are well fupplied with every neceffary of life, and every article of luxury. About 3000 cattle and fheep are brought into the town weekly. The market days are Wednefdays and Saturdays. Liverpool fends two members to parliament. The number of electors amounts to above one thoufand. The corporation confifts of a mayor, two bailiffs, and a common-council. The mayor and bailiffs are affifted by a recorder, a town clerk, and other neceffary officers. The revenues of the town are very great. Enfield's Hiftory, &c. of Liverpool, folio. A General and Defcriptive Hiftory of Liverpool, by Wallace, 8vo 1797. The Picture of Liverpool, 12mo. 1805. Beauties of England, vol. ix.

Lock

LOCK, a well-known inftrument for fecuring doors and preventing them from being opened, except by means of the key adapted to it. A common lock confifts of a ftrong bolt, which muft be fitted in a proper box or cafe affixed to the door, and inclofing it on all fides, to defend it from violence, that it cannot be withdrawn, except by the application of the key, which fhould enter the lock by a fmall key-hole, and be furrounded by numerous wards, that occafion the paffage the key paffes through, in turning round to move the bolt, to be very crooked and intricate, and thus preventing the introduction of any inftrument or falfe key to withdraw the bolt. The third part of the lock is the tumbler, which is a catch or click holding the bolt from being withdrawn, except the tumbler is firft removed by the key, which is done at the fame time it fhoots the bolt. This common lock cannot be made perfectly fecure from being picked or opened without the right key, from the circumftance that the wards, though they may be varioufly difpofed, fo as to require a very crooked key, muft be always left fixed in the lock, and their figure may be taken by introducing a fmall falfe key, covered with wax or other plaftic fubftance, and receiving the impreffion of the wards, from which information a falfe or fkeleton key may be made, that will enter the lock and withdraw the bolt; or, if it will only raife up the tumbler, the bolt may fometimes be forced back by other means. Another reafon of the infufficiency of the common lock is, that the variations capable of being made in the arrangement of the wards are not fufficient to produce the required number of locks without having great numbers exactly alike, and their keys capable of opening each other reciprocally; from which circumftance they become but an imperfect fecurity, as any ill-difpofed perfon may, by furnifhing himfelf with a great variety of old keys, be enabled to open almoft any common lock; particularly if thefe keys are filed away to fkeletons, that is, leaving as little as poffible of the folid part of the key, which will then have a greater chance of paffing in between the intricate wards.

To produce a lock which would be free from thefe objections has been the ftudy of many ingenious mechanics, whofe various locks have different properties and advantages. We have devoted *Plate* XXI. *Mifcellany*, to the explanation of two capital locks, one by Mr. Thomas Rowntree, which is an improvement upon the common tumbler-lock, and another by Mr. Jofeph Bramah, which is on an entirely different principle.

Mr. Rowntree's lock is reprefented in *figs.* 5, 6, 7, and 8; in thefe the following parts are thofe of the common lock: A A is the plate which inclofes the whole mechanifm, and faftens it to the door; B B, *fig.* 6, is the bolt, which is guided in its motion by fliding under two bridges C, D, fcrewed to the main plate; E, E, are four pillars which fupport a plate to cover the works: this plate has the key-hole in it; F, &c. are the circular wards furrounding the centre pin; and *a*, *fig.* 6, is the key which, in turning round, acts in a notch *r* in the bolt, and fhoots it forwards or backwards; G is the tumbler: it is a plate fituated beneath the bolt and moving on a centre pin at *d*. See alfo *fig.* 8, which is a feparate view of the tumbler; it has a catch *e* projecting upwards from it, which enters the notches *f*, or *g*, *fig.* 6, in the bolt, and thus firmly retains the bolt; the former when it is locked, and the latter when it is drawn back. H is a fpring which preffes the tumbler forwards; the key *a*, in turning round, acts firft againft the part *c c* of the tumbler, and

raises it so as to remove the catch *e* from the notches *f* or *g*, and then the key enters the notch *r* in the bolt, and moves it. In this, which is the common lock, it will be seen there is no security, except what arises from the intricacy of the wards F surrounding the key; for a false key, or any other instrument which is of the same length as *a*, will, if it can pass the wards, raise the tumbler and draw back the bolt. Mr. Rowntree has, by applying an ingenious contrivance to this lock, rendered it so secure, that it will be nearly impossible to pick or open it with any other than the true key. To the tumbler he has added a piece of metal *b*, *figs*. 7 and 8, called its *fin*, fixed to its lower side. When the tumbler is locked in the notches *f*, *g*, of the bolt, the fin applies itself to a cluster of small wheels I, *figs*. 5 and 8, all fitted on one centre pin beneath the tumbler: the edges of these wheels stop the fin *b*, and prevent the tumbler being raised; but each wheel has a notch *i*, *fig*. 8, cut in its circumference, and when they are all placed, so that every notch is turned to the side opposite the fin of the tumbler, and forming one notch through the whole cluster of wheels, then the fin is at liberty to enter this notch, allowing the tumbler to rise: but when the tumbler is down, and the plain edges of all or any of the wheels are presented to the fin, the tumbler cannot be raised unless the wheels are first put into the right position above-mentioned: this is done by a number of levers K, *figs*. 5 and 7, all centred on one pin at *k*. At the opposite end each has a tooth *m*, entering a notch in the wheel belonging to it, so that when any lever is pressed outwards it turns its wheel round. The levers are pressed towards the key by a spring *n* applied to each, and in this state they rest against a pin *o* fixed in the plate. The wheels are now disarranged completely, every one presenting its plain edge to the fin, but every one requiring a different degree of motion to bring the notch round to the proper position. When the key is introduced and turned round, it first operates upon the curved part *p q*, *fig*. 5, of the levers K, and raising them, turns all the circles I at once into the proper position. The key, in turning farther round, operates on the part *c c*, *fig*. 6, of the tumbler, now at liberty to move, and by raising it releases the bolt, and in turning still further round, it seizes the notch *r* of the bolt, as in *fig*. 6, and shoots it. The key is cut into steps of different lengths, as shewn at *v v*, in *fig*. R: each step operates on its respective lever K in a different degree, and turns its circle I the proper quantity. The notch at *s* acts upon the tumbler, and the plain part *t* moves the bolt. In this lock there is no possibility of picking it, for if all the levers except one were raised the proper quantity, that one would detain the tumbler as effectually as the whole number; and a false key, besides having the wards as R, must have all the notches *v*, *v*, of the exact depth, neither greater nor less, or it will not open the lock, even if one alone is incorrect. If the key is lost, when a new one is made, the maker takes out the levers K and circles I, and arranging them in a new order, one upon the other, making the new key to fit the new arrangement, and then the old key will not open the lock; though none of the parts are altered, but only their arrangement. The same may be done if it be suspected that an impression has been fraudently taken from the key to make a false one by.

The locks invented by Mr. Joseph Bramah display great ingenuity, and demand a particular description, having been in very general use for many years past, and greatly admired. He obtained a patent for his invention in 1784, and established a manufactory of them, in which he employed a number of ingenious tools and engines for the fabrication of the different parts. One of Mr. Bramah's simplest forms of a lock for a drawer, or for a door, is represented in *figs*. 1, 2, 3, 4, *Plate* XXII. *Miscellany*, in which A represents the bolt, fitted to slide on the metal plate B B C, by passing through a hole in the side C, which is turned up, as shewn in *fig*. 3: the other end of the bolt is guided by passing under proper grooves in the lower side of the circular box D D, which is screwed to the plate B to confine the bolt down. It contains the whole mechanism of the lock, consisting of an interior cylinder or barrel E E, shewn in the section *fig*. 3, with its appendages in perspective in *fig*. 4. This barrel is fitted to turn round within the box D D, the upper end *a a* being received into a cavity exactly fitting it, and the middle encompassed by a circular ring of steel plate *b b*, screwed into the box as shewn in *fig*. 3, and one-half shewn at *b*, *fig*. 4. The ring enters a circular groove formed round the barrel, and thus confines it from having any other motion than a rotation on its axis, and this only by the aid of the key R, as will be explained. The barrel has a hole through its centre, which is closed at bottom by a circular plate F, screwed to it, and supporting the central pin G, which occupies the centre of the hole through the barrel: this centre pin guides the key in entering the lock. When the barrel E E is turned round by the key, it shoots the bolt A, by an ingenious contrivance, explained in *fig* 2, an aperture being cut through the plate B B C to exhibit it. The plate F, on the lower end of the barrel E, has a pin *f* projecting from it: this pin enters a curved opening, at a small distance from the centre, and therefore describes a circle when the barrel is turned round, cut through the bolt A, as is shewn by the dark curve F in *fig*. 2. In the position there shewn the bolt is withdrawn, and the pin *f*, resting against the solid part of the groove, prevents the barrel being turned round any farther in the direction from F to *f*: but by the application of the key, the barrel may be turned in the other direction from *f* to F, in which course it passes round in a circular part of the groove, and therefore produces no motion of the bolt A, until the pin *f* strikes the straight part *g* of the groove, and acts against it to throw the bolt forwards: and when the barrel has made a complete circuit, and the pin *f* is again come to the same position it was at first, the bolt is shot out as at *fig*. 1, and the pin is resting in the hollow *h*, which prevents it moving any farther in the same direction. When the barrel is turned back again, the pin *f* acts against the notch *i* and the curved part *k* of the groove, and withdraws the bolt into the position of *fig*. 2: now the pin *f*, either when the bolt is shot out or in, is in a right line with the centre of the barrel E, to which it is fixed, and the direction of the bolt's motion. By this means, no force whatever applied to drive back the bolt can have the least tendency to turn the barrel round, and strain the mechanism which prevents its motion, unless the parts are first put into a particular arrangement, by the application of the key. The interior mechanism must be explained by *fig*. 4, in which *l*, *m*, *n*, represent small steel sliders, which are fitted into proper grooves or slits, made in the substance of the barrel E. Of these there are six in number, arranged round the barrel, and projecting a little from its exterior surface in the small part. These sliders are received in notches *y*, *z*, in the fixed steel ring *b b*, before described; and thus effectually detain the barrel at six points from being turned round, except it is first unlocked by the key R being introduced at the key-hole H, and the sliders pressed down by it, so as to bring the notches (of which each slider has one, as at *r* *fig*. 4) all opposite the steel plate *b b*, and then the barrel may be turned round. When the key is absent, the sliders are raised up by a brass ring *v* sliding on the central pin G, and lifted up by a spiral spring *w*. The key has six notches cut in the end of it, as shewn at S, which is an end view: each notch in the key includes one of the six sliders *l*, *m*, *n*,

and the key, being forced down into the key-hole H, depresses all the sliders at once, until the projecting leaf *t* of the key stops upon the bottom of the recess *x*, cut in the upper edge of the barrel. In this position the sliders are depressed, so that the notch *r* made in each slider comes exactly opposite the steel ring *b b*, and the barrel is at liberty to turn round all the sliders, being by this means removed, or at least relieved, from the steel ring, which, as before mentioned, embraces a groove cut round the barrel, but which cannot turn round therein unless the sliders are also moved by the key, that the notches cut in them coincide with the groove cut round the barrel, and then it can turn freely round. The key, having thus relieved the barrel by being thrust in as far as it can go, obtains a hold of the barrel to turn it round, by the leaf *t* entering the recess *x*, which it exactly fills up, so as to form a continuation of the circular top of the barrel: but as soon as the key is turned round with the barrel a small quantity, its leaf is caught beneath the circular cavity in the top of the box D, and thus the key is prevented from being thrown out by the spiral spring *w*, until it has been turned quite round, and locked or unlocked the bolt: then the leaf of the key coming opposite the enlargement *z*, *fig*. 1, of the key-hole H, the spring throws the key out and raises all the sliders, that they may interlock with the steel plate *b b*, and prevent the barrel from turning, unless the key is again put in, (its leaf being opposite the aperture *z* of the key-hole,) and being thrust forwards as far as it will go, the barrel will turn round very easily; and when it has made a complete circuit, the lock is opened, and the key thrown out of the key-hole by the spring.

The security of this ingenious lock from being picked, or opened by a false key, depends upon a circumstance not yet mentioned, which is, that the notches in the six sliders are so made, that every one requires to be depressed a different quantity to bring them all at once opposite the steel ring, in which position alone the barrel can be moved. For this reason the six notches in the key are all of different depths, correspondent to the positions of the notches in their respective sliders; and unless each notch in the key is of the proper depth, the lock cannot be opened, for any one being too deep, that slider will not be pressed low enough to relieve the barrel, and will hold it fast, though all the others may be correct: on the other hand, any notch not being of sufficient depth, the slider it acts upon will be pressed too far, and in this case the notch in it, having passed by the steel ring, will lock the barrel as effectually as though it was not far enough. Thus this lock admits of an immense number of combinations; 1st, in the number of the sliders; 2dly, the depths of the different notches in the key; and 3dly, the arrangement of these sliders. The combination of these three changes admits such an immense number of varieties of locks, that it never need happen that two locks should be made to open by the same key. Any of Mr. Bramah's locks may be arranged so as to require a new and different key in case the original should be lost or stolen: for this purpose the lock must be opened, and the sliders taken out and changed into different grooves: a new key must now be made, with the grooves of the same depth of the original key, but arranged in a different order, corresponding with the new arrangement of the sliders. The old key will not now open the lock.

To pick a lock of this kind is perhaps impossible; because, though the sliders are exposed to the examination of any person, yet no information can be obtained of the depth of each of the sliders required to be depressed; for, unless they are all together pressed down, the barrel cannot be turned in the least, and without turning it, no guess can be made by pressing down any one slider of the depth at which the notch in it will be opposite the steel ring. Another great advantage of these locks is, that from the circumstance before explained, of the bolt having no action to turn the barrel, though the barrel has a great power to shoot the bolt, a strong lock may have but a very small key. For instance, the bolt of the lock, in the plate which is drawn its full size, is of great strength, while the key R is so small, that it may always be carried suspended to the watch chain, and then it will not be in danger of being lost or mislaid, as one may happen to lose a key, and give opportunity for ill disposed persons to make a false key from it, unknown to the owner.

A lock invented by Mr. Stansbury, an American gentleman, has great merit. To explain it, we must suppose that a flat circular plate is fitted to turn round upon the centre pin for the key, and that this plate, when turned round, shoots the bolt, which may be done by various means. The locking part consists of four, six, or more small steel pins, which are received in holes made very near each other, through both the circular turning plate, and the fixed plate beneath it. By these pins the circular plate is held fast from turning. The key has the same number of pins, and arranged in the same position and distance as the pins in the plate. The key being introduced, it is pressed forwards against the circular plate, and turned round till the pins in it come over the pins in the circular plate, and the pressure of the hand forces the pins out of the circular plate, the pins in the key occupying the place of them. The plate is now relieved, and the key has hold of the plate to turn it round and open the lock. Each pin is provided with a spring behind the fixed plate to force it forwards. The difficulty of making a false key to this lock is very great; as any error in the number, size, position, or length of the pins, will prevent it from opening the lock. To avoid the danger of impressions being taken, many marks are stamped upon the circular plate, which are exactly the same at the marks of the real pins: thus an impression taken from it would only mislead.

Mr. Stansbury has also made an ingenious improvement upon the common spring door-lock. The handle which opens the spring catch for fastening the door, instead of requiring to be turned round, is made so that it withdraws the spring catch, by pushing the handle on one side of the door and pulling it on the other. This method is extremely convenient; for pressing the handle releases the lock, and continuing the pressure opens the door, and pulling the handle on the other side has the same effect. A person with his hands full may open such a door by only leaning against the handle.

Lock, or *Weir*, in *Inland Navigation*, the general name for all those works of wood and stone, made to confine and raise the water of a river: the banks also which are made to divert the course of the river, are called by these names in some places. But the term *lock*, or *pound-lock*, is more particularly appropriated to express a contrivance, consisting of two gates, or pairs of gates, called the lock-gates, and a chamber between, in which the water may be made to coincide with the upper or lower canal, according as the upper or lower gates communicating with it are opened; by which means boats are raised or depressed from one level or reach of a canal to another. See *Plate* V. *Canals*.

Lock *of Water*, is the measure equal to the content of the chamber of the locks, by which the consumption of water on a canal is estimated.

Lock-*keeper*, a person who attends the locks to take

care of them, and to affift the boatmen in paffing through them.

LOCK-*paddles* are the fmall fluices that ferve to fill and empty the locks.

LOCK-*fils* are the angular pieces of timber, (*b*, *b*, *Plate* V. *Canals*, *fig*. 36.) at the bottom of the lock, againft which the gates fhut.

LOCK-*weirs*, or *Paddle-weirs*, are the over-falls behind the upper gates, (*z*, *z*, *Plate* V. *fig*. 35.) by which the wafte-water of the upper pound is let down through the paddle-holes into the chamber of the lock.

Lode

LODE, in *Mining*. This word is derived from the Anglo-Saxon, according to Dr. Pryce, and is ufed by the Cornifh miners to defignate any regular vein, whether metallic or not. More commonly, however, it means a metallic vein.

The lodes that are found to contain tin and copper ores, in Cornwall and Devon, have their general direction in a line running nearly eaft and weft; their dip or *underlay* being more commonly to the north; though fome which incline to the fouth have been very productive. Veins which interfect the eaft and weft lodes are called *crofs-lodes*, or *crofs-courfes*, when their direction is nearly at right angles with the others; and *caunters*, more generally, when their direction is oblique.

The metallic eaft and weft lodes are traverfed or difturbed by the crofs-courfes, and thefe interruptions are known by the name of *heaves*, which take place to very different degrees of extent, and vary much in the circumftances under which they are found; fo that miners do not agree upon any certain rules for determining the diftance or direction of the heave by the accompanying appearances.

Though copper and tin are found but partially in crofs-lodes, yet lead has been raifed in large quantities from fome that have nearly a due north and fouth courfe; fuch as the Beeralftone lead-mines and Wheal Betfy lead-mine in Devon. Eaft and weft lodes have fometimes a mixture of lead ores with copper; but this appears to be derived from the interfection of a crofs-courfe, or the effect of a later depofit. Lodes traverfe all kinds of rock found in the line of their direction, whether vertically or horizontally. Thofe worked in Cornwall and Devon are chiefly in killas or grauwacke flate; but they are fometimes in granite, and pafs not unfrequently from the former into the latter.

The width of veins varies from an inch or two to fifteen or twenty feet; the latter dimenfion being rare, as the former is unprofitable to follow, unlefs in the expectation of an enlargement. The more common width, or, as the miners call it, *the fize of lodes*, is from two to four feet; and if fuch a vein as this be fully impregnated with metal, it is

very profitable to work, and is called a good *courfe of ore.* The variations of width take place not only in diftinct veins, but in one and the fame; which, together with the fluctuations in the nature of their contents, render their produce fo uncertain. A large and productive lode often dwindles to a mere *branch*, requiring an experienced eye to diftinguifh it from the rock through which it paffes; and this again expands to a confiderable fize, filled with depofits of various kinds. The width of lodes feems often to have a relation to the nature of the rock in which they are found; and changes in the latter appear generally to produce changes in the former. Thus, a vein that is large and productive in foft blue killas, will, by paffing into harder, become lefs in fize, and barren as to metallic contents. Another lode may be rich in hard ground, but poor and unproductive in that which is of a fofter kind: but this is not fo frequent as the former cafe. The depofits of metal are as irregular in the lodes as the widths of them; and fo much fo, as to render the profits of mining proverbially uncertain. Ore is generally found to occupy certain parts of the veins only, differing conftantly in extent, whether the length or depth on the courfe of the vein be confidered, or the portion of its width which is filled up by it. No lode has been found regularly impregnated with metal to any great extent; and therefore, when ore is found, it is in what the miners aptly call *bunches* or *fhoots*. The unproductive parts of veins, even in the moft profitable mines, generally far exceed in extent the productive parts; but that mine is confidered to be rich, which has either frequent or extenfive fhoots of ore: the great art of the miner, therefore, confifts in tracing and working the valuable accumulations of the metals with as little wafte of labour and expence on the poorer ground as poffible.

Although the bunches of ore have no regular form in their vertical or horizontal extent, yet the tendency to a certain direction or dip in the lode may be obferved in each bunch or fhoot of ore. Thefe fhoots are frequently parallel in the fame vein; and where the dip or underlay of the lode is to the north, the fhoots of ore may frequently be obferved to dip weft in the lode. In veins underlaying fouth, the bunches of ore frequently have their dip to the eaft: but this is not to be taken as a general rule, as many mines afford exceptions to it; the underlay of the lode and the dip of the bunches of ore being reverfed.

Thefe tendencies or inclinations of the depofits of metal in the veins, connected with the fituations, dips, and bearings of the veins themfelves, feem to offer grounds for argument on the difputed queftion of the mode in which the metals were depofited; but they have not much, we believe, attracted the notice of mineralogifts.

Lodes continue to indefinite lengths, and to unknown depths. It is very difficult to determine whether the end of any regular vein has been found or not; as there are many inftances of their having become fo fmall as to be fcarcely vifible, and yet afterwards, on purfuing them, to have refumed their ufual fize. When a lode has continued fmall, either in length or depth, to any confiderable extent, it is moreover ufually abandoned as unpromifing; and thus complete evidence as to this queftion is not obtained.

Lodes are perfect in the furface of the mountains, as well as in their greater depths; and may be traced uniformly by removing the foil with which the rock is covered. This is done conftantly by the miner when he is about to undertake operations upon a newly difcovered vein. This procefs is called *cofteening*, or *fhoding*. The width of a lode at the furface is no certain indication of its fize in depth: as, when large at the furface, they are fometimes found to become fmall as they are purfued downwards; and, on the other hand, veins of moderate width *at grafs* have been found, at 40 or 50 fathoms deep, of great fize.

The dip or inclination of lodes is feldom uniform. The common *underlay* is from one to four feet in a fathom of depth; but inftances occur of a much greater inclination. The lodes that incline much from the perpendicular are not efteemed fo promifing as thofe which have a direction more downright; and it is a favourable fymptom when a lode, from an oblique direction, is found to turn downwards. On the contrary, where bunches of ore *fail*, or become poor, in finking on them, it may often be obferved that the vein *goes away flat*, as miners exprefs it. Thus it will be underftood, that not only are the dips different in feparate lodes, but that the fame vein frequently varies in this refpect. Lodes have been obferved to change their underlay, that is, from dipping to the north, to become perpendicular, and even turn to the fouth. This is not, however, a matter of frequent occurrence.

The underlay of lodes muft be afcertained, when it is intended to fink perpendicular fhafts to meet them at certain required depths; and from this is determined the diftance to be fet out north or fouth from the back of the vein, for commencing fuch fhafts.

Shafts are often funk *upon* the lodes, and of courfe thefe are not perpendicular, but have the fame inclination as the veins.

Levels driven from the fhafts, are carried on in the fubftance of the lode, follow its direction, and are the principal means by which difcoveries of ore are made and purfued.

The principal methods by which lodes are difcovered are the two following: 1. By removing the foil covering the furface of the rock, by which the back of the vein is laid bare, and expofed to view. This may happen accidentally, in the formation of roads, ditches, and fo on; or, as is more ufual, it may be done for the exprefs purpofe of difcovery, in confequence of indications of veins being near at hand, fuch as detached fragments being found, or fprings of water impregnated with metal being obferved. This procefs is conducted by finking trenches, or pits, deep enough to reach the furface of the rock, called by miners the *fhelf;* which trenches are called *fhoding pits*, or *cofteening pits*. The detached fragments, wafhed from the backs of lodes, are ufually called *fhodes*, or *fhode-ftones*.

The fecond mode of difcovering veins is by levels, or horizontal cuts, driven under ground, which in their progrefs through the rock, or, as the miners fay, acrofs *the country*, interfect and expofe lodes before unknown. Such levels muft have a direction acrofs the ufual courfe of the lodes, and are either conducted for the exprefs purpofe of finding new veins, or for fome other object; and then may occafionally be the means of valuable refults of this fort.

Many rich mines have been opened, in confequence of a difcovery made by carrying on an adit, or by driving a crofs level from a fhaft, or from one lode to another known to be parallel to it. The practice of driving adits for the purpofe of difcovery is more frequent than it ufed to be. The Taviftock canal has a long tunnel driving through a hill, deftined principally for this purpofe, and which has already been attended with very great fuccefs.

Lodes feldom contain ore near the furface of the ground: it is, therefore, an effential quality in a miner's judgment to decide on the indications prefented by them, and to determine the amount of rifk which their appearances will warrant on a further trial.

There are niceties in this bufinefs which cannot be de-

ſcribed, but muſt be ſeen and ſtudied to be underſtood, and with which ſkilful miners are converſant; but the moſt experienced is liable to have his predictions falſified by the fluctuating nature of theſe hidden receptacles of various matter.

The indications moſt depended on, in forming a judgment of the value of a lode, are derived from conſidering the following circumſtances:

1. The nature of the ſubſtances contained in the vein.

2. The kind of rock in which it is found.

3. The width and regularity of the vein, conſidering, at the ſame time, its direction and dip.

4. The ſtructure of the vein, ſuch as the being open and pervious to water, or, on the contrary, hard and cloſe.

Theſe ſymptoms may be, on the whole, conſidered as pertaining to veins containing all kinds of metals, though varying in ſome in a certain degree: thus a hard cloſe lode may be favourable for tin, though not ſo for copper or lead.

When a vein is found exhibiting all or moſt of the appearances which experience has determined to belong to thoſe which are productive, it is called a *kindly lode*, and is generally purſued with vigour, and at an expence proportioned to the prevalence and continuance of the favourable ſymptoms.

We ſhall endeavour to conſider the principal indications, according to the order above ſtated, and point out the leading facts to be obſerved in this important branch of a miner's buſineſs.

I. *Of the nature of the ſubſtances contained in the vein.*

Theſe ſubſtances vary according to the depth to which the lode is opened; thoſe near the ſurface being generally different from the contents of the vein deeper under ground.

The firſt thing for which a miner looks is what in Cornwall is called *goſſan*. This ſubſtance does not appear to have been very accurately deſcribed, but is apparently a decompoſed mineral of an iron-ochre colour, varying from yellow to brown-red and chocolate-brown. It is of a ſpongy, cellular texture, of little ſpecific gravity, and is generally ſoft and friable. It is probably the reſult of the decompoſition of pyrites or mundic, together with quartz, and contains a conſiderable portion of iron, and not unfrequently a mixture of tin and copper ores. When theſe latter are preſent in the combination, it is a moſt favourable ſymptom; but even without them, goſſan on the back of a lode warrants a trial to a certain extent. It can by no means be aſſerted, that the moſt promiſing goſſans have always been followed by ore, on a further purſuit; but perhaps there is hardly an inſtance of a lode rich in ore, which has not a bunch of *kindly goſſan* ſomewhere on the back.

The next ſubſtance, proceeding in depth, upon which reliance may be placed, is *mundic*, including in this name pyrites of all kinds, whether arſenical or ſulphuretted, containing iron or copper. Mundic is found at all depths and in all ſituations in veins: it frequently ſurrounds bunches of copper ore, and is therefore a favourable ſymptom, as they are approached; and indicates their decline, when paſſed through on the other ſide. It ſhould, however, be recollected, that mundic is very generally found, and therefore it muſt not be depended on by itſelf.

The earthy ſubſtances, which are eſteemed favourable to the exiſtence of valuable metallic ores, are principally quartz, going under the general name of ſpar; a kind of clay called *flookan*; and, what is not very abundant, *fluor*, diſtinguiſhed by the appellation of *candied ſpar*.

The firſt and the chief ingredient in veins, *quartz*, is kindly, when it is in a looſe friable form, often cryſtallized, and cementing detached fragments of killas and the other ſubſtances before enumerated. It is unpromiſing when in a cloſe amorphous form, and is then termed a *ſharp hungry ſpar*.

The *flookan*, or clay, generally forms a branch or vein on one of the walls of the lode, and ſeems to be the diviſion between that and the rock containing it.

The decompoſition of the adjoining ſtrata ſeems to have been the origin of this ſubſtance, which is called by ſome foreign writers the *ſaalbande*.

Beſides fluor, on which miners are not well agreed as to its promiſing aſpect, and which is not often found in quantity, are ſome other minerals, likewiſe of not very frequent occurrence, but eſteemed favourable; ſuch as *prian*, a kind of decompoſed quartz, and *peach* or chlorite.

Hitherto we have ſaid nothing of the judgment formed by ores found in a lode; it depends upon the following circumſtances:

1. The ſituation, whether ſhallow or deep.

2. The mode of depoſit, whether ſlightly ſprinkled through the lode, or forming ſhoots or bunches of large or ſmall extent.

3. The quality of the ore.

Under the firſt head, moſt miners agree that, as to copper lodes, rich bunches of ore found near the ſurface are not to be depended on as ſhewing that a mine will be very productive; it having often been found that ſuch depoſits have been followed by poverty at a greater depth. Tin and lead are found nearer the ſurface than copper. When a lode is ſpotted with ſmall quantities of ore, and the other ſubſtances are kindly, ſuch as the goſſan and ſpar, the appearance is promiſing; but when the lode is hard, and in other reſpects unkindly, then ſmall ſtrings of ore are not to be reckoned on as particularly favourable. After a certain depth, a regular branch, or, as it is called, a *leader* of ore of any width, occupying part of a good-ſized vein, and increaſing or even fluctuating in ſize as it is purſued, is on the whole the beſt ſymptom, particularly if connected with favourable accompanying ſubſtances.

Under the head of quality of the ore as an indication of future proſperity to a mine, it muſt be remarked that nothing requires to be received with greater caution than promiſes of ſucceſs ſuppoſed to be derived from the richneſs of individual ſpecimens. We are ſpeaking now more particularly of copper lodes. Few, we believe, of the moſt profitable mines produce much ore of the richer varieties, which indeed is ſeldom found to occupy veins of conſiderable width: on the contrary, moſt of the beſt mines are thoſe which yield ore in large quantities, but poorer in metallic content. This obſervation has been likewiſe made on the ſilver mines of South America, according to the account of Humboldt. Copper ores are found in a greater variety of ſpecies near the ſurface than they are in depth; and therefore the miner's experience only will ſerve to diſcriminate perfectly on this point: but we wiſh to put all who are concerned in mining on their guard againſt a fallacious hope, too frequently excited by the aſſay of a ſtone of ore, which in reality often predicts the very reverſe of what it is ſtated to do by the artful or ignorant.

II. The ſecond indication to be attended to, in eſtimating the proſpect of ſucceſs on a particular vein, has been ſtated to be *The kind of rock in which it is found.*

It is unneceſſary here to go into a voluminous account of rocks, becauſe the great mines of England, as well as of the world, being found in ſuch mountains as are conjectured to be of very early formation, do not admit the varieties in this reſpect, which ſome, who are acquainted only with

other diſtricts, where probably a later formation has exhibited different phenomena, might conjecture.

Lead-mines, indeed, exiſt in many parts of England, in various rock, and under various circumſtances; but no general rules of mining can be formed from depoſits of a metal, which appears to have taken its place at a period comparatively late. Such rules can only be applicable to ſeparate diſtricts, where the circumſtances attending the depoſits are ſimilar.

There are two general claſſes of rock which claim the diſtinction of metalliferous above all others. Theſe are the *killas* of the Corniſh miner, or grauwacke or tranſition ſlate of Werner; and granitic rocks, including porphyry, gneiſs, and other varieties, known in Cornwall by the general name of *growan*.

Of theſe the great majority of mines are in killas, or grauwacke, not only in Cornwall and Devon, but in Scotland, in the Hartz, in the Saxon Erzgebirge, on the Rhine, in Bohemia, Sileſia, Moravia, Salzburg, and other diſtricts important for their mineral products.

Granitic rocks are not ſo metalliferous as the *killas*, but productive veins are found in them; and, as Dr. Berger has well obſerved in his account of Devon and Cornwall, in the firſt volume of the Tranſactions of the Geological Society, even the killas is not a depôt of metallic veins to any extent, but near its junction with the granite: and this obſervation had been made, as he ſays, by baron Born and Ferber on the mines of the continent.

This fact of moſt mines being in one prevailing rock, would ſeem to ſimplify the exerciſe of judgment in a miner ſpeculating on the effect of the rock upon the contents of a lode. But though killas is ſo univerſal, it is far from being all alike: on the contrary, it conſiſts of many varieties. Theſe varieties do not alternate according to certain rules, like the beds of ſecondary rocks; but exhibit changes in poſition and extent, more or leſs frequent, and moſt uncertain and capricious.

The varieties of killas, which are eſteemed the moſt kindly for copper, are the blue and the white, more eſpecially if of a tender, ſlaty texture. Tin often is found in abundance in harder killas, more irregular in its ſtructure, and of a darker colour, indicating the preſence of iron. Practice alone can enable men to judge of the ſhades of difference in theſe reſpects, which long experience has pointed out as eſſential to be attended to: and even then, allowance muſt be made for exceptions which frequently occur; rules which ſeem to hold good, when applied to one mine, being often inapplicable to another.

III. The third thing to be conſidered is *The width and regularity of the vein, and its direction and dip*.

Theſe are important circumſtances. If the lode be ſmall, it cannot be expected that abundant depoſits of metal can be found; and if it has not the characters belonging to a regular fiſſure, it is probable that the miner will ſoon be diſappointed, by finding it dwindle to a trifling branch, or ſplit into several inſignificant ramifications.

Every large and productive lode is accompanied by other veins running parallel to it, or nearly ſo, which often fall into the main lode, and generally enrich it by their junction.

Theſe muſt be carefully attended to, and ſought after, as the changes that they produce are often moſt important, and the quantity of ore which they yield is frequently very great. It has indeed been aſſerted, that there is hardly a mine working on a ſingle vein only, which has been profitable to any great degree.

The direction of the lode ſhould be carefully aſcertained; becauſe certain ores are only found in veins which have their courſe in common with others having ſimilar depoſits in the diſtrict.

Thus the writer of the preſent article has obſerved that copper and tin, in Cornwall, muſt only be expected in lodes running eaſt and weſt; while lead is raiſed from ſuch as have a direction at right angles to them, or from north to ſouth.

The more uſual dip or underlay, in copper mines particularly, is to the north; but ſome lodes that underlay to the ſouth have been very productive. In either caſe, it is no favourable ſymptom to find the inclination from the perpendicular to be great; and it may be ſaid to be ſo, if it exceed four feet in the fathom.

When a lode often ſplits or divides into two or more branches, it is ſubject to fluctuation in its produce; and theſe occurrences are important to be noticed with attention, as they afford prognoſtics as to the future ſucceſs of working.

IV. The fourth and laſt head, under which we have arranged the appearances of productive lodes, is that relating to *The ſtructure of the vein, whether open or porous, and thus pervious to water; or, on the other hand, denſe and cloſe, and conſequently dry*.

All miners agree in this, that water being found to be abundant in a lode is an omen of a very favourable nature; and it is often confidently aſſerted, that no large returns of ore have been made from dry veins. As far as the experience of the writer of this article goes, it ſerves to confirm the obſervation.

Water, indeed, may be found paſſing freely through croſs-courſes, and other veins, from which metallic depoſits are abſent; but then ſuch veins will be found to have all the characters which are adduced as proofs of a later formation, and are therefore eaſily diſtinguiſhed from metallic veins.

Large lodes act as natural underdrains, and are channels through which water percolates; ſo that the rock lying on either ſide may often be ſunk upon with but little interruption from water until the vein is cut into, and then abundant ſtreams flow out, and would put an end to further labour, if it were not for the aid of proper engines to get rid of it.

The quantity of water will of courſe be, in ſome degree, proportioned to the extent of the wide and porous parts of the lode; and, as it is from theſe parts only that much ore can be expected, the water forms in the firſt inſtance a pretty good prognoſtic.

If, in driving upon the courſe of a ſmall, cloſe, and unproductive lode, a ſtream of water be ſuddenly met with, it indicates the approach to an enlargement in the vein, and is a moſt favourable ſymptom; and it is, in point of fact, almoſt always obſerved before a good courſe of ore is ſeen.

The mines of Devon and Cornwall abound with water in a much greater degree than perhaps any others; and as evidence of this, we may adduce the number of vaſt ſteam-engines and overſhot water-wheels employed for the ſole purpoſe of draining them. We believe, likewiſe, that when the quantities of ores raiſed in this diſtrict be compared with thoſe of any other which yield them from *true veins*, they will be found abundant in the ſame proportion.

Under the head of the internal ſtructure of lodes may be noticed the cavities, called by the Germans *druſes*, and by the Corniſh miners *voogs*: theſe are obſerved moſt frequently in large veins, and in ſuch, of courſe, aſſiſt in the paſſage of water, and may be claſſed in the ſame place as a favourable indication. In theſe voogs are found all the varieties

of cryftals; and thus the prefence of thefe in a lode is likewife confidered promifing, more particularly where obfervations are made on a vein at no great depth: for as the mine becomes deeper the lode often becomes more compact, and the miner calculates upon finding *folid courfes of ore.*

In connection with this part of the fubject, the *walls* which enclofe the vein are not to be difregarded, when the lode itfelf is confidered, as they fhould be found to be well determined, fmooth, and regular. The rock of which they are formed fhould be of the hard fchift called by miners *capel;* and if penetrated with traces of ore, it may be confidered as a fymptom of large depofits. On each fide of the walls, which ufually differ fomewhat from the adjoining rock, as if altered by the prefence of the vein, the ftrata may generally be obferved to be twifted or bent downwards, in a flight degree towards the lode, which is in general confidered to be more the cafe near large veins than near thofe which are fmaller.

Having now detailed the principal characteriftics of lodes, as important to the practical miner, defcribed the modes of difcovering them, and the fymptoms by which a judgment is formed of their contents, as far as relates to working them for the metals; we leave the confideration of them, in a geological point of view, for the article VEIN. The operations of working upon them will be defcribed under the head of MINING, and under that of ORE.

LODE, in *Rural Economy*, a provincial term applied to fignify ford, in fome diftricts.

Logwood

LOGWOOD, in *Botany*, the wood of a tree; for the botanical characters of which, see HÆMATOXYLUM. The wood of this tree is brought in logs of about three feet in length, to Europe, where it is used for dyeing purples, and for the finest blacks; and therefore it is a very valuable commodity.

The use of logwood in dyeing was established in this country by 13 & 14 Car. II. cap. 11. before which time it was prohibited as a pernicious material. A considerable part of the soluble portion of the wood is taken up both by water and alcohol, but much more by the latter, and these menstrua become tinged by it of a deep purple-red or brown. If acids be added to the watery decoction, it is turned yellow, but alkalies give a very deep purple colour, without yielding any precipitate. Alum, added to the decoction of logwood, causes a violet precipitate or lake, and the supernatant liquor also remains violet, and gives a fresh portion of lake on the effusion of an alkali. The salts of iron give an inky black with all the solutions of logwood, under the same circumstances as with galls, whence the presence of gallic acid in logwood is evinced. The solutions of tin form a very fine violet-coloured lake with the decoction of logwood, and wholly precipitate the colouring matter, so that the supernatant liquor is quite clear and colourless. In dyeing, logwood gives its own natural purple, with shades or variations according to the mordant used, or it heightens and improves the common black with iron and galls. In this latter way it gives a peculiar gloss and lustre, on which account it is a very valuable dyeing material.

Logwood is used in miniature painting to make a purple wash; which may be varied to a more red or blue colour by the addition or omission of Brazil wood. The wash may be prepared by boiling an ounce of ground logwood in a pint of water, till one-half of the fluid be wasted; strain it then through flannel, while of a boiling heat; and add to it, when strained, about ten grains of pearl-ashes. To make it more red, add half an ounce of Brazil wood, or in proportion as the colour wanted may require; using in this case the pearl-ashes very sparingly. This wood has a sweetish subastringent taste, but a remarkable smell. It gives a purplish-red tincture to watery and spirituous infusions, and tinges the stools, and sometimes the urine, of the same colour; but it does not appear to colour the bones of animals.

Besides its use among dyers, it is employed medicinally as an astringent and corroborant. In diarrhœas it has been found peculiarly efficacious; also in the latter stages of dysentery, when the obstructing causes are removed, it serves to obviate that extreme laxity of the intestines usually superinduced by repeated dejections. Extractum ligni campechensis is ordered in the pharmacopeias, and may be given in the dose of one scruple or two, repeated according to the urgency of the symptoms. The extract is obtained by inspissating the decoctions. To promote the extraction, the wood should be reduced into a fine powder, which is to be boiled in the water, in the proportion of a pound to a gallon, till half the liquor is wasted. Some digest the powdered wood in as much spirit as will cover it to the height of about four inches, and afterwards boil it in water; the matters taken up by the watery and spirituous menstrua may be united into one extract, by inspissating the watery decoction to the consistence of honey, and then gradually stirring in the spirituous tincture.

LOGWOOD *Country*, in *Geography*, a district of America, that lies N.W. of the Mosquito shore, at the head of the bay of Honduras, and extends from Vera Paz to Yucatan, from 15 to 18° N. lat. The whole coast is overspread with islets, keys, and shoals, and the navigation is intricate.

LOGWOOD *Lagoon*, a bay or gulf on the N.E. coast of Yucatan. N. lat. 20° 57'. W. long. 88° 20'.

LOGWOOD *Mill*, in the *Manufactures*, is a machine for reducing logwood, or other dyeing woods, to small chips or raspings, that the colouring matter may be more readily extracted from them by the dyer. These machines are of two kinds: one, by means of knives fixed to a large wheel, chips the wood across the grain into small fragments, which are afterwards reduced to a fine powder, by grinding them beneath a pair of rolling stones: this is called a chipping engine. The other kind operates by steel bars, with a great number of notches in the edge, which rasps and cuts the end of the wood into powder: this is called the rasping engine. Both machines

require an immenſe power to actuate them, and are generally worked by water-wheels or by ſteam-engines. A plan and elevation of a raſping engine is given in *Plate* XXXI. *Mechanics, figs.* 1 and 2, where A is an iron cog-wheel, turned round by the large cog-wheel of a water-mill or ſteam-engine; its axis has an iron cylinder B fixed upon it, and this has a number of ſteel bars or knives *a* fixed in its circumference. The pieces of wood to be raſped are placed in a ſtrong wooden trough, D D, in which an iron bar, E, ſlides, and forces the wood down to the cylinder, being moved by two racks, F, F, turned by pinions on an axis, G. At one end of this is a handle, *g*, and at the other a wheel, *h*, which is turned by a pinion, *k*, at the extremity of a long ſpindle, H I, which is turned by a wheel, K, whoſe teeth are engaged by threads of a worm or endleſs ſcrew, *l*, cut on the end of the main axis. By this means the pinions are conſtantly turning round with a very ſlow motion, and advance the wood towards the cylinder, which is at the ſame time in motion, and its raſps cut the wood into powder. A ſection of the raſp cylinder is ſhewn in *fig.* 3, where the ſame letters are uſed. In this *m* is the groove in which tenants at the ends of the bar, E, ſlide. This bar has many large ſpikes in it, which faſten into the wood. At *n* is a ſtrong iron plate at the end of the trough, to defend it from wearing away by the great preſſure of the wood down upon it. The wood is kept down in the trough by the croſs-bar, L, *fig.* 2, fixed down over them. The iron cylinder, B, is caſt with 24 grooves in it lengthways, and in theſe are laid as many ſteel bars, Y, Z, *fig.* 3, the ſection of which is X. The angle, *r*, being ground to a ſharp edge, and the ſide, *r s*, cut with teeth, as ſeen at Z, ſo that the edge is ſerrated, as ſhewn by Y, the knives are held in their grooves by a ſtrong hoop, *n*, *fig.* 2, driven on the ends of the cylinder over the knives, and they are wedged in faſt by ſmall iron wedges. When the wood in the engine is all raſped, and it needs a freſh ſupply, the pinion, *k*, is diſengaged from the wheel *h*, and then the winch, *g*, being turned by a man, the racks are withdrawn. To diſengage the pinion, *k*, its bearing is fixed in a beam, O, which ſwings on a hinge at the upper end, and the lower end has a rod, *p*, jointed to it, which is engaged by a catch, *r*, when the handle, *t*, at the extremity of the rod, is moved away from the cylinder, ſo as to engage the pinion, *k*, with its wheel, *h*. But on moving the end of the rod towards the cylinder, it is relieved from the catch, and the pinion is diſengaged from the wheel; and to prevent the bar, E, going ſo far as to endanger its teeth meeting the raſps, a pin is fixed into a particular part of one of the racks, *f*, which takes hold of the rod, *p*, when it has got as far as intended, and removes the rod from the catch, *r*, and then the racks do not advance any farther to the raſps. The wheel at R S, joining in the axes H and I, is called a friction box: it conſiſts of an iron box, R, fixed on the end of the axis, I; its cavity receives a conical plug, S, fitted upon the end of the other axis, H, and preſſed into the box by a lever, T, loaded with a weight. By this means, if the wood does not raſp away ſo faſt as the motion of the racks would advance it, the cone, S, ſlips round in the box, R, and allows for the difference of the movements, which would otherwiſe break the machine. The cylinders of raſping engines generally turn round from 15 to 20 times per minute, and will reduce a great quantity of wood to a powder in a ſhort time. *Figs.* 4 and 5 are two elevations of a *chipping engine:* here A is part of a ſtrong iron axis, turned with a conſiderable velocity by water or ſteam: upon the end is a ſmall circular flanch, B, to which is bolted a circular iron-plate, D, in which four knives are fixed, ſo that their edges project a very ſmall quantity before the ſurface of the wheel in the manner of a plane iron. E is an iron frame containing the bearing for the pivot of the wheel; it has a ſmall trough, F, caſt all in one piece with it. All this iron work is ſcrewed down to the wood framing, G G. The wood, H, is in this machine preſented to the knives in the wheel by a man who holds it in the trough, and advances it as the knives cut away the end. Theſe chips are cut acroſs the grain but obliquely, as is evident from *fig.* 4: they are afterwards ground to a fine powder by a rolling ſtone, or runner upon edge. A large and heavy fly-wheel is uſually fixed on the axis, A, of the chipping wheel to regulate its movement. A method of reducing logwood has been lately introduced by ſawing it with a circular ſaw (ſee SAW), which cuts off a flake from the end of a piece of wood *x*, ſo that the jar of the ſaw ſhatters the flake all into powder. By this means, at every cut the ſaw cuts away as much wood as its thickneſs in ſaw duſt and the flake, which is as much more, is reduced at the ſame time, ſo that all the wood is reduced, though only one-half is cut, whereas, in the raſping engine, every particle muſt be cut by the machine. This improvement merits the attention of the woollen manufacturers, whoſe numerous logwood mills would be much improved by the adoption of this method.

London

LONDON, the metropolis of the Britiſh empire, the moſt wealthy, moſt extenſive, and probably the moſt populous and powerful city in the world, is ſeated in a fertile and ſalubrious plain or valley, on the banks of the river Thames, which divides the town into two irregular parts, and paſſes through it, from the weſt to the eaſt, in its progreſs to the ſea. Many cities and towns of antiquity have been famous in the annals of nations: Nineveh was noted for its towers and walls of vaſt circumference, height, and breadth; Babylon, for the hanging gardens, and other objects of human labour; Perſepolis, for its natural fortifications; Palmyra and Balbeck, for ſumptuous buildings; and Athens and Rome, for the civilization, refinement, and high accompliſhment of their inhabitants. But London may be denominated the modern wonder of the world. The prodigious increaſe of houſes, inhabitants, trade, commerce, and wealth, with the refinement and luxury which now prevail, render it ſuperior to all the cities of modern Europe; and muſt excite the aſtoniſhment of ſuch foreigners and Engliſhmen as have ſtudied the local and comparative hiſtories of places of note. It may be regarded as the focus of the Britiſh empire; for within its juriſdiction are concentrated the royal, legiſlative, juridical, civil, commercial, ſcientific, and literary concerns of Great Britain. Many writers have been employed, at different periods, to narrate the annals of this great town; and ſeveral volumes in folio, quarto, octavo, &c. have been excluſively devoted to the topographical hiſtory of London: but all are imperfect and unſatisfactory: the largeſt works being moſtly tedious, trivial, and prolix; and the ſmaller publications are very ſuperficial and inaccurate. At the end of this account will be given a liſt of ſeveral of theſe works; to point out the ſources of the preſent

essay, and to furnish the reader, who may require more circumstantial information, with a guide to facilitate his researches. The following article will comprehend a general view of the history and local characteristics of this metropolis, with some particular descriptions; but for detailed accounts of many buildings, places, and objects, the reader is refered to the following heads, in different parts of this work: BANK *of England*, BRIDEWELL, BRIDGES, COMPANY, list of 91 in London, and accounts of the principal; COLLEGE *of Civilians*, or *Doctors-Commons*, COLLEGE *of Heralds*, COLLEGE *of Physicians*, COLLEGE, *Sion*, COLLEGE *of Surgeons*, COLLEGE, *Veterinary*, ROYAL EXCHANGE, CUSTOM *of London*, DOCKS *of London*, EXCISE, FLEET-*Prison*, *Gresham* COLLEGE, GUILDHALL, HOSPITALS *of Bethlehem*, *Bridewell*, *Christ*, and *Foundling*, INNS *of Court*, INSURANCE *Companies*, ISLINGTON, LAMBETH, HACKNEY, MARY-LE-BONE, PADDINGTON, MIDDLESEX, SURRY, NEWINGTON-BUTTS, THAMES, POLICE, PARLIAMENT, NEW-RIVER, LIMEHOUSE, STRATFORD-LE-BOW, SOUTHWARK, WESTMINSTER.

The centre of London, or St. Paul's church, is ascertained to be in latitude 51° 31′ N., and in longitude 5′ 37′ W. of Greenwich, where the royal national observatory is established. The distance of London from the principal cities of Europe is as follows: from Edinburgh 395 miles S.; from Dublin 338 S.E.; from Amsterdam 190 miles W.; from Paris 225 miles N.N.W.; from Copenhagen 610 miles S.W.; from Vienna 820 miles N.W.; from Madrid 860 miles N.E. by E.; from Rome 950 miles N.N.W.; from Constantinople 1660 miles; from Moscow 1660 miles E.S.E.; from Stockholm 750 miles; from Petersburgh 1140 miles; from Berlin 540 miles; and from Lisbon 850 miles.

London, as considered in the aggregate, comprises the city and its liberties, with the city and liberties of Westminster, the borough of Southwark, and nearly thirty of the contiguous villages of Middlesex and Surry. The greatest portion is built on the northern bank of the Thames, or in Middlesex; whilst Southwark, with Lambeth, and several connecting villages, extend along the southern shore of the same river, in the county of Surry. The extent of London, from west to east, or from Knightsbridge to Poplar, is full seven miles and a half; whilst its breadth, from north to south, or from Newington Butts to Islington, is nearly five miles. The circumference of the whole, allowing for various inequalities in the extension of streets, &c. at the extremities, cannot be less than thirty miles. Hence it may be fairly estimated, that the buildings of this metropolis cover at least eighteen square miles, or 11,520 square acres. Out of this must be deducted the space occupied by the river Thames, which extends about seven miles, or 12,320 yards in length, by one quarter of a mile. or 400 yards in width; making 1120 square acres.

Independently of various local and civil divisions, London may be said to consist of five distinguishing parts, or popular portions; *viz.* the west end of the town, the city, the east end of the town, Westminster, and the Borough. The "west end of the town," extending from Charing-Cross to Hyde-park, and from St. James's park to Paddington, is considered the best and most fashionable part of the town, and is laid out in the two great thoroughfares, called Oxford road and Piccadilly, with various handsome squares and streets, which are chiefly occupied by the town-houses of the nobility and gentry, and the most fashionable shops. The "city" includes the central part, and most ancient division of the metropolis. This is the emporium of commerce, trade, and business; and is occupied by shops, warehouses, public offices, and houses of tradesmen and others connected with business. The "east end of the town," and its inhabitants, are devoted to commerce, to ship-building, and to every collateral branch connected with merchandize. This division of London has assumed a novel character since the commencement of the present century, by the vast commercial docks and warehouses that have been formed and constructed here. The southern bank of the Thames, from Deptford to Lambeth, bears some resemblance to the east end of the town; being occupied by persons engaged in commercial and maritime concerns; docks, wharfs, and warehouses being abundant. But this part of London has one distinguishing feature from any other, as it abounds with numerous and various manufactories; iron-founderies, glass-houses, soap-boilers, dye-houses, boat-builders, shot and hat manufactories, &c. and many other similar establishments. From the great number of fires employed in these houses, and offensive effluvia arising from some of the works, this district is rendered extremely unpleasant, if not unhealthful, for human residence. It is therefore mostly inhabited by workmen, labourers, and the lower classes of society. Many improvements have lately been made, and several respectable houses erected on St. George's fields. In Westminster are the houses of lords and commons, the courts of justice, and many offices belonging to government. Another part of the metropolis, not hitherto noticed, but which may be considered as the last enlargement, and the most regular and systematic in its arrangement of squares, streets, &c. is the northern side of the town; comprehending a large mass of new buildings between Holborn and Somers-town, and in the parishes of Mary-le-bone and Paddington. Nothing shews the increased and increasing growth of the English metropolis more decisively than the vast number of new squares, streets, rows, and places, that have been recently erected, and are now in the progress of building, all round the metropolis. London is computed to contain nearly 70 squares, and 8000 streets, lanes, rows, courts, &c. According to a census obtained in the year 1811, the population of London, Westminster, and their suburbs, was 1,099,104 persons; being an increase of 133,139 within the course of ten years. Well might Cowper exclaim,

"Opulent, enlarged, and still increasing London."

It would be both amusing and interesting to trace the progressive growth or expansion of London; to describe it at different and remote periods; and delineate, with a careful and accurate pencil, the natural and artificial, the political and civil, the moral and commercial characteristics of the British metropolis, at different epochs. Some of these features will be noticed in the progress of our survey; but many must necessarily be omitted, from the peculiar nature of the present publication.

Ancient History and Antiquities of London.—It is generally admitted by topographers, that the present scite of London was occupied as a British town before the arrival of the Romans. Of this, however, there is no evidence: for Geoffrey of Monmouth is not to be trusted, nor is his assertion entitled to respect. We are informed by Tacitus, that about the year 61, Londinium, or Colonia-Augusta, "was the chief residence of merchants, and the great mart of trade and commerce, though not dignified with the name of a colony." (Ann. lib. xiv. c. 33) Boadicea, the amazonian queen of the Britons, headed a large body of natives, and, after conquering Camalodunum and Verulam, took posses-

fion of Londinium. At this time, it appears that Londinium was not fortified in the Roman manner, and was inferior to either of the other places juft named. In a few years afterwards, the Romans made it a permanent ftation; furrounded it with a fortified wall of ftone and brick, and governed the inhabitants by Roman laws. The courfe and extent of the walls were as follows: commencing at a fort, near the prefent tower of London, the wall was carried in a line directly north to Ald-gate; thence it made a curve to the fouth-weft, to Bifhops-gate, from which it continued in a ftraight line to Cripple-gate and Alders-gate; here it turned to the fouth, and proceeded to New-gate, where it made almoft a right angle, turning to the fouth, to Lud-gate, and on to the banks of the Thames. The circuit of this part of the boundary, according to Stow, was nearly two miles and one furlong. Another wall, of about one mile in length, extended along the northern bank of the Thames, from the fort near the Tower to another fort near the prefent Black-friars bridge. Thefe walls were defended, at different diftances, by ftrong towers and baftions. The height of the wall is faid to have been 22 feet, and the towers 40 feet. The fuperficial contents of the area thus enclofed have been computed at about 400 acres. Nearly through the middle of this ftation paffed a ftream, fince called Wall-brooke. Dr. Stukeley, in his "Itinerarium Curiofum," has given a plan of Londinium, fhewing the extent and form of the ftation, with the number of gates in the walls, and the military roads that branched off from it. The burial-places were without the walls, on the north and eaftern fides of the town. Londinium was advanced from a *præfecture, i. e.* a town governed by a Roman præfect, to the rank of a colony. It alfo became the feat of the vicarius Britanniarum, and of the commiffioners of the treafury under the Roman emperors. To enter into accounts of all the various remains of the Romans, which have been difcovered at different times within the limits of London, would lead us into a long differtation: it muft fuffice to ftate, that teffellated pavements, urns, coins, pottery, foundations of buildings, and other evident relics of the Romans, have been frequently found beneath the prefent furface. At the Bank, near the India houfe, and in Lombard ftreet, fome pavements have been taken up; and in various other parts of the city have been found evident traces of Roman habitations, and Roman cuftoms. The London ftone in Cannon ftreet is confidered, by moft antiquaries, as part of a Roman milliary. Thefe are all particularly defcribed in Brayley's Survey of London and Middlefex, vol. i. 1810.

Very little is known of London during the Anglo-Saxon dynafty; nor do we know of any buildings, or other local antiquities, which may be referred to that period. Under the Saxons, London, then called Lunden, Lundone, Lundenburg, Lundenes, Lundenceafter, gradually increafed in extent and affluence; and, according to Bede, it then became the "emporium of many nations." Religious edifices were erected in the feventh century, on the fcites of St. Paul's and Weftminfter Abbey. It is prefumed there was a bridge acrofs the Thames, near Weftminfter, previous to the year 994: as William of Malmfbury, when fpeaking of the repulfe of the Danes under Sweyn and Olaf, fays that "part of them were drowned in the river, becaufe, in their hafty rage, they took no heed of the bridge." In the time of king Athelftan, a law was paffed refpecting coinage, by which it is fpecified that London was allowed eight minters, whilft only feven were appointed for the cities of Canterbury and Winchefter.

Soon after the Roman conqueft, a fortrefs or caftle was built on the banks of the Thames; and this was enlarged by Gundulph, bifhop of Rochefter, who erected the White tower, within the Tower of London. In the fame reign St. Paul's church was commenced; and the ftrong caftles of Baynard and Montfichet, both of them ftanding on the banks of the Thames within the city walls, were erected by two of the Norman king's officers, named Baynard and Montfichet. During this and feveral fucceeding reigns, the public buildings of London were greatly augmented in number, by the erection of feveral religious edifices, abbatial and epifcopal refidences. The royal palace at Weftminfter, which had been founded by Edward the Confeffor, was confiderably enlarged; and a large hall was built there by William Rufus. The reign of Henry I. was diftinguifhed by the foundation and conftruction of many monaftic houfes; and feveral others were eftablifhed during the Anglo-Norman and Plantagenet dynafties.

A lift of the religious houfes, with the time of their different foundations, will afford a tolerable idea of the gradual increafe of the city, with refpect to fuch eftablifhmeets, and of the difference between ancient and modern London. The town appears to have contained no lefs than fifty-four monaftic houfes, fuch as abbies, priories, nunneries, hofpitals, colleges, &c.

St. Paul's cathedral was firft founded by Ethelbert, king of Kent; church rebuilt in 961; again in the time of William Rufus. The prefent church commenced in 1675.

The priory of St. Martin-le-Grand, founded by Withred, king of Kent, in the year 700; was given, in 1502, by Henry VII. to Weftminfter Abbey; the ftreet of St. Martin-le-Grand is ftill annexed to Weftminfter.

The nunnery in Clerkenwell, founded in 1100, by fir Jordan Brifet.

The hofpital of St. John of Jerufalem, in Clerkenwell, was founded in 1100, by the fame.

The Holy Trinity, or Chrift-church, within Ald-gate, was founded by the emprefs Maud, in 1108, for Auftin canons.

The priory of St. Bartholomew in Weft Smithfield was begun by Rahere, in 1123; the hofpital foon afterwards.

A Benedictine nunnery of Haliwell, by Robert Fitz-Gelran, before 1127.

St. Katherine near the Tower, by the emprefs, before 1148.

The Old Temple of Holborn, in 1118; and the new one near Fleet-ftreet, by the order, in 1185.

St. Mary Spittle, by Walter Brune, in 1197.

St. Thomas of Acre, in the end of Henry II.'s reign, by Thomas Fitz-Theobald.

The college of Allhallows Barking, by Richard I.

The nunnery of St. Helen's, in Bifhopfgate-ftreet, was founded by William Fitz-William, in 1210.

The Black Friars had a houfe near Chancery-lane, but afterwards begged or bought the ground near Caftle Baynard, foon after 1221.

The Grey Friars, about 1224; afterwards in Newgate ftreet.

The White Friars, by fir Rich Grey, in 1241.

A priory for Auftin Friars was eftablifhed in Broad-ftreet, by Humphry Bohun, earl of Hereford, in 1253.

The Friars of the Sack, Old Jewry, 1257. Order diffolved, 1307.

The Croffed or Crutched Friars, by Ralph Hofier and William Saberns, in 1298.

The Rolls, or Domus Converforum, by Henry III. in 1231, for the converfion of Jews.

St. Mary Rouncivall in the Strand, about the fame period.

The hospital or priory of St. Mary of Bethelem or Bedlam, was granted by Simon Fitz-Mary, in 1247.

The convent of St. Clare, in the Minorics, by Edmund earl of Lancaster, in 1293.

A college and hospital, called Elsing Spittle, were founded by William Elsing, a citizen, in 1329.

Sir John Pountney founded a college in Cannon-street, in 1332

St. Mary of Graces, or East-Minster, a Cistertian abbey, was founded by king Edward III. in 1350.

The Charter-House, before 1370, by sir Walter de Manny, and Michael de Northburgh, bishop of London. See CHARTREUSE.

The hospital of the Savoy, in 1505, by Henry VII.

Besides these, the guilds or fraternities of London were very numerous. There was a brotherhood and chapel of the Holy Trinity in Leadenhall, and several others were founded in most churches. The grand suppression of the whole commenced in 1537. Exclusive of the religious houses, the bishops and parliamentary abbots had each a town residence of state

The abbot of St. Austin's, Canterbury, house was in the parish of St. Olave's, Southwark.

The abbot of Evesham's, in the parish of St. Catherine Cree.

The abbot of Reading's, at Beynard castle, in the parish of St. Andrew Wardrobe.

The abbot of St. Mary's, York, at St. Peter's Place, Paul's Wharf.

The abbot of Glastonbury, in West Smithfield.

The abbot of Hyde, in the parish of St. Mary at Hill.

The abbot of Ramsey, in Whitecross-street.

The abbot of Bury St. Edmund's, in St. Mary-street, Aldgate.

The abbot of St. Alban's, in Lothbury.

The abbot of Peterborough, in the parish of St. Gregory.

The abbot of Salop, near St. Bartholomew's, West Smithfield.

The abbot of Leicester, in the parish of St. Sepulchre.

One instance of the service which was rendered to the public, even in London, by the monastic institutions, is worthy of note: the priory of St. Mary Spittle contained, at its dissolution about the year 1536, no less than 180 beds for the reception of sick persons and travellers. The hospitals which were suffered to remain, owed their continuance to sir Richard Gresham, mayor of London, in 1537, who petitioned the king to bestow the lands belonging to this, St. Bartholomew's, St. Thomas's, and the new abbey on Tower-hill, on the corporation, for the relief and use of the poor, the sick, and the vagrant.

Annals of London, from the Departure of the Romans to the Accession of Edward I.—When the Romans, from the distracted state of the empire, found it necessary, in the early part of the fifth century, to withdraw their troops from the distant provinces, London again became a British town, and is mentioned in the Saxon chronicle in the year 457, when the Britons fled hither on their defeat by the Saxons under Hengist, who, about twenty years afterwards, made himself master of London; but on his death, in 498, it was retaken by Ambrosius, and retained by the Britons during a considerable part of the next century. It afterwards became subjected to the newly-established Saxon kingdom of Essex. On the conversion of the East Saxons to Christianity, London was nominated as the bishop's see, Melitus being appointed the first bishop in the year 604: a cathedral church was erected in 610, on the scite of the present St. Paul's. During the period of the Saxon heptarchy, but few notices of London appear to have been recorded. In 664 it was ravaged by the plague; and in 764, 798, and 801, it suffered severely by fires; in that of 798 it was almost wholly consumed, and great numbers of the inhabitants perished. On the union of the Saxon kingdom under Egbert, London, though not the royal residence, or seat of government, as has been erroneously stated, was advancing in consequence, as appears from a Wittenagemot having been held here in 833, to consult on proper means to repel the Danes. By these invaders London was repeatedly pillaged and laid waste. In 925 king Athelstan had a palace here; the city increased in importance under the Danish sovereigns, and under Edward the Confessor; and on the successful invasion of William the Conqueror, the magistrates of London, conjointly with the prelates and nobility, invited him to accept the title of king of England. From this period London may be considered as the metropolis of the kingdom.

William, at the commencement of his reign, granted a charter to the citizens, which is beautifully written in the Saxon characters, and is still preserved among the city archives: it consists of only five lines on a slip of parchment, six inches long and one broad. In the year 1077 the greatest part of the city was destroyed by fire. In the following year the king founded the fortress, now called the White Tower, for the purpose of keeping the citizens in awe, as he had reason to suspect their fidelity. In 1086 another fire consumed the principal part of the city, together with the church of St. Paul. Maurice, then bishop of London, laid the foundation of the new church: "a worke," Stow observes, "that men of that time judged would never have been finished, it was then so wonderful." It is remarkable that Domesday book, though so minute in regard to other cities and towns, does not contain any notice of London. A vineyard is mentioned in Holborn belonging to the crown, and ten acres of land near Bishopsgate (now the manor of Norton-Falgate) belonging to the dean and chapter of St. Paul's. In November, 1090, above 600 houses and several churches were blown down by a tremendous hurricane, and Stow says, "the Tower of London was also broken." About two years afterwards another destructive fire happened. In the succeeding years William Rufus repaired the Tower, and strengthened it by additional works; and in 1097 he built a great hall at Westminster. Henry I., as a reward for the ready submission of the Londoners to his usurped authority, granted to the city an extensive charter of privileges, among which was the perpetual sheriffwick of Middlesex. On the death of Henry, the Londoners took a decided part in favour of Stephen in his contest with the empress, and greatly contributed to his establishment on the throne. In the first year of his reign a fire, beginning near London Stone, consumed all the houses eastward to Aldgate, and westward to St. Paul's, together with London bridge, which was then of wood. Henry II. does not appear to have held the citizens in any great degree of favour, probably resenting their attachment to Stephen: and we find that large sums of money were extorted from them under the specious name of Free-gifts. In 1176 the building of a new bridge of stone was commenced at London, but was not completed till the year 1209. On the coronation of Richard I. a dreadful massacre of the Jews, who were settled in London, was made by the brutal and ignorant populace. At the coronation-dinner, the chief magistrate of London, who at that time had the title of bailiff, acted as chief butler. Early in this

reign the appellation was changed to that of mayor, in the person of Henry Fitz Alwyn. Richard granted the city a new charter, confirming all its liberties, with additional privileges; and four years afterwards, on payment of 1500*l.* he granted another, providing for the removal of all weirs that had been erected on the river Thames; on this charter the corporation of London found their claim to the conservatorship of that noble stream. In 1196, a sedition arose in London, headed by William Fitz Osbert, who excited the common people to oppose the government, and gained associates to the amount of 50,000; but the leader being taken and executed, the commotion subsided. This is one of the first instances upon record of a tumultuous assemblage in defence of popular rights. In the reign of king John the civic importance of London was greatly increased; and its corporation finally assumed that form and predominancy, which, with a few alterations, it has maintained till the present time. John granted the city several charters; by one he empowered the "barons of the city of London" to choose a mayor annually, or to continue the same person from year to year, at their own pleasure. In 1212 a dreadful calamity took place, through a fire which commenced at the bridge end in Southwark, and occasioned a destruction almost unparalleled from such a cause: Stow relates that about 3000 persons perished. During the contest between the king and pope Innocent III. London severely felt the consequences of the interdict which was laid upon the kingdom. In the civil feuds, which marked the latter years of John, the Londoners sided with the barons; and when the humbled monarch was compelled to sign Magna Charta, it was therein expressly stipulated that the "city of London should have all its ancient privileges and free customs as well by land as by water." The long reign of Henry III. affords but few events worthy of notice respecting London: its growing prosperity was checked by a series of extortions and oppressions. In 1258, the price of corn was so excessive, that a famine ensued, and according to the chronicles of Evesham, 20 000 persons died of hunger in London only. In 1264 another massacre of the Jews took place; on a plea that one of that persecuted race had taken more than legal interest, and upwards of 500 Jews were put to death by the populace, and their houses and synagogues destroyed.

Annals of London from the Accession of Edward I. *to that of Henry* IV. In the year 1279 all the Jews in England were apprehended in one day, on a charge of their being the authors of the great mutilations which had taken place in the coin during the preceding reign: 280 persons of both sexes were executed in London, besides many others in various parts of the kingdom. Between the years 1314 and 1317 the city, in common with the rest of the kingdom, suffered greatly from a scarcity of provisions, which eventually produced a complete famine. King Edward III., on the commencement of his reign, granted to the city two charters: by the first all the ancient privileges were confirmed and additional ones bestowed; by the other, the village of Southwark was granted to the citizens in perpetuity. In 1348, the terrible pestilence, which, breaking out in India, spread itself westward through every country on the globe, reached England. Its ravages in London were so great, that the common cemeteries were not sufficiently capacious for the interment of the dead; and various pieces of ground without the walls were assigned for burial places: amongst these was the waste land now forming the precinct of the Charter-house, where upwards of 50,000 bodies were then deposited. This destructive disorder did not entirely subside till 1357. The public entry of Edward the Black Prince into London, May 24, 1356, after the victory he obtained at Poictiers, was celebrated with an unparalleled degree of splendour; and every street through which the cavalcade passed, exhibited an extraordinary display of riches and magnificence. The captive king of France, dressed in regal robes, was mounted on a white courser, while the victorious prince rode by his side on a small black horse, and appeared more like an attendant than a conqueror. In 1361, the plague having again broke out in France, every precaution was taken to prevent its spreading into England, but without effect; the pestilence reached London, and its ravages were so destructive, that upwards of 2000 persons fell victims in two days. In 1363, a sumptuous entertainment was given in the city by Henry Picard, alderman, to the kings of England, France, Scotland, and Cyprus, to Edward the Black Prince, and to a great number of nobility and gentry. The year 1378 is memorable in the city annals for the expedition fitted out by an individual, John Philpot, against Mercer, the Scottish pirate, who taking advantage of the inattention of government to naval affairs, carried off all the shipping from the port of Scarborough; and continuing to infest the northern coast, frequently made considerable prizes. The complaints of the merchants were but little regarded by the council; when Philpot prepared a fleet at his own expence, with a thousand men well armed, went himself on board as commander-in-chief, and sailed in pursuit of the pirate. A long and desperate engagement ensued; but Philpot obtained the victory, and obliged the pirate to surrender, with most of his ships, among which were fifteen Spanish vessels richly laden. In November 1380, the fourth year of Richard II. an act of parliament was passed for levying a poll-tax on every person in the kingdom, male or female, above the age of fifteen years. This act was the occasion of producing, in the following year, one of the most dangerous insurrections that ever threatened the monarchy of this kingdom; and in which the metropolis particularly suffered. The tax was exacted with great rigour; and the insolence of the collectors was an additional cause of irritation, and kindled the sparks of sedition which soon after burst into an open flame. The insurrection began in Essex, but quickly spread through the neighbouring counties, and particularly in Kent, where the daughter of Wat Tyler, so called from his trade, having been indecently treated by a collector, the father killed him, and being supported by the insurgents, placed himself at their head. To his standard incredible numbers flocked from all parts of the kingdom; and on the 10th of June, 1381, having mustered on Blackheath a hundred thousand strong, they entered Southwark, where they set at liberty the prisoners from the King's Bench and Marshalsea prisons, and levelled the houses of all lawyers. They burnt the archbishop's palace at Lambeth, with the rich furniture, books, and registers, and destroyed the public stews which were then tolerated on Bankside. For one day the bridge gate was shut against them; but they were afterwards, from prudential motives, admitted into the city. They then proceeded to the palace of the Savoy, which was one of the most magnificent structures in the kingdom. Having set fire to it in several places, they caused proclamation to be made, that no person should convert any part of the rich effects to his own use, and actually threw into the fire one of their companions who had reserved a piece of plate. They also burnt the Temple and the other inns of court. Dividing into three parties, one advanced to the rich priory of St. John of Jerusalem, near Smithfield, which they burned; a second division marched to the Tower, where they seized sir Robert Hales, lord treasurer, and Simon

Sudbury, archbishop of Canterbury, and lord chancellor (though guarded by 1200 soldiers), and hurrying them to the adjacent hill, beheaded them; the third division proceeded to Mile End, where the king met them, and promised to redress their supposed grievances, on which they dispersed. But Wat Tyler, with his party, under the pretence of reforming abuses, continued their ravages in London, liberated the prisoners from the Fleet and Newgate, plundered the houses of the Lombards who resided in the street, which yet retains their name, and dragging the merchants from the churches, whither they had fled for refuge, beheaded them in the streets. Not content with murdering many of the most eminent citizens, they made proclamation for beheading all lawyers and persons connected with the Exchequer, and even all who, in those days of ignorance, were capable of writing. The king made another effort for negociation: attended only by forty horse, he met Tyler with 20,000 of his adherents in Smithfield. The behaviour of Tyler was so insolent, that the king ordered the mayor, sir William Walworth, to arrest him; on his resistance, sir William felled him to the ground with his sword, and the attendants dispatched him. The rebels prepared to revenge their leader's death; but Richard, though only fifteen years of age, with a prudence and bravery which did him more credit than any other action of his life, rode forward, exclaiming, "My friends, will you kill your king? Be not troubled for the loss of your leader; I will be your captain, and grant what you desire." They then marched under his direction to St. George's Fields, where, finding a thousand citizens completely armed to oppose them, they threw down their weapons, obtained their pardon, and immediately dispersed. Thus ended an insurrection unparalleled in the annals of this kingdom, and which for three weeks seemed to threaten a total subversion of the government. In 1390, the king appointed a tournament to be held in London, and sent heralds to proclaim his intention to all the principal courts of Europe, whence many princes and nobles came to attend the spectacle, which was continued with the greatest splendour for four days; open house being kept at the king's expence for all persons of distinction. The vast expenditure which this and similar festivities occasioned, frequently reduced Richard to great pecuniary difficulties; his enormous profusion led him to a system of oppression and extortion, which eventually caused his deposition and death.

Annals of London from the Accession of Henry IV. *to that of Elizabeth.*—At the coronation of the new king, the mayor, as usual, officiated as chief butler. The citizens were gratified by the repeal of some obnoxious statutes, and an extension of their privileges. In 1401, an act was passed for "burning obstinate heretics," entirely aimed at the Lollards, or followers of Wickliffe. The first victim was William Santree, parish priest of St. Osyth, in Syth-lane, London. In 1407, the Plague again ravaged the kingdom, and swept away more than 30,000 of the inhabitants of the metropolis. In 1409, "a great play, of Matter from the Creation of the World," was acted at Skinner's-Well, near Clerkenwell. The exhibition lasted eight days; at which were present the king and most of the nobility and gentry of the realm. In the following year, John Bradley was condemned as a Wickliffite, and burnt in Smithfield, with circumstances of peculiar cruelty. In this year Guildhall was erected; the city hall before being a mean cottage in Aldermanbury. The return of king Henry V. after the glorious victory obtained at Agincourt in 1415, was celebrated in London with great magnificence. Neither this reign nor the following produced any events of peculiar import to the city, till the year 1450, when a new insurrection arose, of so formidable a nature, that for some weeks all the power of the crown was insufficient to quell it. This tumult is supposed to have been raised by the instigation of the duke of York, in order to sound the inclination of the people, and prepare the nation for his design of seizing that sceptre which Henry swayed so feebly. By the secret instructions of the duke, Jack Cade, who had served under him in the French wars, assumed the name of Mortimer, and collected a strong body of malcontents, under the popular pretext of redress of grievances. They entered the city in triumph, and for some time bore down all opposition; and beheaded the lord treasurer, lord Say, and several other persons of note. The insurgents at length losing ground, a general pardon was proclaimed, and Cade, finding himself deserted by his followers, fled: but a reward being offered for his apprehension, he was discovered, and refusing to surrender, was killed. The remainder of this reign was filled up with the dreadful contest between the Lancastrians and Yorkists, which ended in the deposition of Henry and the establishment of Edward IV. on the throne. The year 1472 will ever be memorable in the annals of the metropolis, for the introduction of printing into this country by William Caxton, citizen and mercer. The history of the kingdom during this reign and that of Richard III. does not in any particular manner affect the concerns of the city. Soon after the accession of Henry VII. in 1485, an epidemical disorder of a very singular nature, called the *sweating sickness*, raged with great violence in London. Those attacked by it were thrown into a violent perspiration, which generally occasioned their death within twenty-four hours. It appears from Hall's Chronicle, that two mayors and six aldermen died of this complaint in one week. This reign was particularly marked by oppression and extortion on the part of the king; and the tumults and insurrections occasioned thereby, particularly that in support of Perkin Warbeck, who was asserted to be Richard, duke of York, and the heir to the throne. In this event, though highly interesting to the kingdom, the city was not immediately concerned. In 1500 the kingdom was again visited by the Plague, of which 30,000 persons died in the metropolis and its vicinity. In the reign of Henry VIII. when he attempted to raise money without the aid of parliament, the citizens made such determined opposition to the measure, and their example had such an influence through the kingdom, that the king, in full council, abandoned his design, and granted a pardon to all who had opposed him. On the king's marriage with Anne Boleyn, in 1533, she was conveyed from Greenwich to the Tower, and thence through the city to Westminster, with all the magnificence and pageantry which unbounded prodigality could devise. The remainder of this reign was notorious for the tyranny and cruelty of the king, who, having thrown off the pope's supremacy, sacrificed all who adhered to it: yet professing a zealous attachment to the doctrines of the church of Rome, he put to death those persons who presumed to differ from him. Hence the promoters of reformation, and its opposers, perished in the same flames; the blood of the Catholic and Protestant was shed upon the same block; and Henry, whilst vehemently contending against the pope's infallibility, supported his own with the most vindictive cruelty. In these sanguinary scenes, London had its full share; great numbers, of all ranks, were continually executed, either for heresy or treason. The suppression of the monasteries now took place: opposition to the king's will was fatal; and the partial insurrections which broke out in consequence, only served to forward his measures, by giving the colour of necessity to the vengeance that was inflicted. Many improvements were made during this reign in the city and its

suburbs. The police was better regulated; nuisances were removed; the streets and avenues were amended and paved; and various regulations were carried into effect for supplying the metropolis with provisions, to answer the demands of an increasing population. In the short reign of Edward VI. the reformation proceeded with steadiness and regularity: but on the accession of Mary the church of Rome again gained the ascendency. On the projected union between the queen and the king of Spain, a formidable insurrection ensued, in which the city was particularly affected: the suppression of this revolt was followed by a dreadful scene of sanguinary triumph. The statutes against heretics were now also enforced with great severity. A number of persons were burnt in Smithfield: in the whole kingdom upwards of 200 were brought to the stake.

Annals of London from the Accession of Elizabeth to the Revolution in 1688.—Elizabeth succeeded her sister amidst the acclamations of all ranks of people. Reformation again reared its head, and was in a short time firmly established. In 1561 the spire of St. Paul's cathedral was struck by lightning, and great part of the building consumed. In 1563 the Plague again made dreadful ravages, to which 20,000 persons fell victims in the city. In July 1566, the foundations of the Royal Exchange were laid by sir Thomas Gresham, and the structure was completed in the following year. The year 1569 exhibited a novelty in London of most pernicious example. The first public lottery was then drawn at the west door of St. Paul's cathedral, and the drawing continued, without interruption, from January 11 to May 6. The prizes were of plate, and the profits were appropriated to the repair of the sea-ports. In 1586 a conspiracy was set on foot to assassinate Elizabeth, and free the queen of Scots from the captivity in which she had passed almost eighteen years. The plot was soon discovered, and the conspirators, fourteen in number, were executed in Lincoln's-inn-Fields. Mary was said to be implicated in the conspiracy; and this, whether true or false, furnished a plausible pretext for those proceedings, which soon after condemned her to the block. The sentence against her was proclaimed with great solemnity at different places in London and Westminster. In the preparations made to repel the threatened attack of the boasted Spanish Armada, London took a most distinguished share, in furnishing large supplies of money, men, and ships. The preparations for the coronation of king James were interrupted by a dreadful Plague, which ravaged the city with greater violence than any similar visitation since the time of Edward III. In 1604, the horrible conspiracy, known in history by the name of the "Gunpowder Plot," the grand object of which was to prepare the way for the restoration of the Catholic religion, was commenced by its daring contrivers, with every possible precaution that seemed necessary to ensure its success. The destruction of the king and parliament was the preliminary measure through which the conspirators thought to accomplish their design; and the blowing up of the parliament-house with gunpowder at the moment when the sovereign should be commencing the business of the session by the accustomed speech from the throne, was the dreadful means by which the destruction was intended to be accomplished. All the principal conspirators were bigotted Catholics, who had for many years been plotting the downfall of Protestantism in this country, and had even applied for aid to Spain and Flanders. Being disappointed of the assistance they required, they resolved to depend on their own efforts, and about Easter 1604, formed the idea of the gunpowder plot, to be carried into effect on the meeting of parliament in February following. Accordingly Percy, one of the conspirators, hired a house immediately adjoining to the house of lords, and the operations commenced by digging through the foundation-wall, which was nine feet in thickness. Just at this juncture, a vault under the parliament-house, used as a depository for coals, was to be let, and the coals to be sold. As nothing could have happened more favourable for their purpose, Percy hired the cellar, and bought the coals, as if for domestic use, and without any appearance of concealment. The prorogation of parliament from February to October gave the conspirators sufficient leisure to further their design; and, at convenient opportunities, thirty barrels and four hogsheads of gunpowder, which had been procured from Holland, were conveyed into the cellar by night, and covered with billets, faggots, iron-bars, and stones. This was done without exciting any suspicion: parliament had again been prorogued to November 5th; and the conspiracy wore every aspect of success. It had now been on foot eighteen months, and confided to more than twenty persons; yet nothing had led a single step towards discovery; when the plan was happily frustrated by a circumstance apparently trivial. One of the conspirators, wishing to save lord Monteagle, sent him a letter, advising him, in ambiguous terms, to absent himself from parliament, on account of a sudden danger to which he would be exposed. This notice Monteagle carried to the secretary of state, who laid it before the privy-council. A secret search was determined on, but, to prevent suspicion, was delayed till the eve of the meeting of parliament, and then made only by the lord chamberlain, as if in a formal discharge of his office. When he entered the cellar, and saw the great store of coals and wood, he enquired to whom it belonged, and was informed the cellar was let to Mr. Percy, and the fuel was for his consumption. The chamberlain heard this with seeming carelessness, and left the cellar with apparent negligence. But at midnight a further search was made; Guy Fawkes, a principal conspirator, to whom the final execution of the plot was assigned, was apprehended in the cellar: the fuel was removed, and the gunpowder discovered. Fawkes gloried in the plot, but refused to discover his accomplices; the sight of the rack, however, subdued him, and he made a full disclosure of the whole conspiracy. His associates fled into Warwickshire, where they endeavoured to excite a rising of the Catholics, but without effect. A proper force was sent againt them, four were killed in resistance, and the rest were taken and brought to London, where, with Fawkes, they suffered the just punishment of their guilt. In the year 1609, the city acquired a considerable accession of power and property: almost the whole province of Ulster, in Ireland, having fallen to the crown, the king made an offer of the escheated lands to the city, on condition they would establish an English colony there. The proposal was accepted; and so rapid was the colonization forwarded, that within seven years arose the two capital towns of Londonderry and Coleraine. The commencement of Charles I.'s reign was marked by the return of the plague, which carried off in the metropolis 35,000 persons. To advert to all the important transactions that took place in London during the eventful struggle between Charles and his people would far exceed our limits. The excessive oppressions to which the nation was subjected, were more particularly felt in the metropolis than in other parts of the kingdom, from its being more directly within the vortex of the star-chamber and high-commission courts, and from the effects of the monopolies, which had a most pernicious influence on trade and

commerce. For the particulars of this important period, we refer our readers to Clarendon's History of the Great Rebellion.

The year 1665 became memorable in London by the dreadful ravages of the great Plague, which first made its appearance in December 1664, and had not entirely ceased till January 1666. Its progress, the first two or three months, was comparatively small, but continued to advance, notwithstanding every precaution was used to abate its fury: from May to October 1665, it raged with the greatest violence; the deaths progressively increased from five hundred to eight thousand weekly. The pestilence was now at its height: its ravages, which commenced in Westminster and the western suburbs, extended through the city to Southwark, and to all the parishes eastward of the Tower. The digging of single graves had long been discontinued, and large pits had been excavated, in which the dead were deposited with some little regularity and decent attention: but now all regard to ceremony became impossible. Deeper and more extensive pits were dug, and the rich and the poor, the young and the aged, the adult and the infant, were all promiscuously thrown together into one common receptacle. Whole families, and even whole streets of families, were swept away together. By day, the streets presented a most frightful aspect of desolation and misery; and at night the dead carts, moving with slow pace by torch-light, and with the appalling cry, "Bring out your Dead," thrilled horror through every heart that was not by suffering hardened to calamity. The stoppage of public business was so complete, that grass grew within the area of the Royal Exchange, and even in the principal streets of the city: all the inns of court were shut up, and all law proceedings suspended. The entire number returned in the bills of mortality, as having died of the plague within the year, was 68,950; yet there can be no doubt that this total fell short, by many thousands, of those who actually fell by the infection, but whose deaths were not officially recorded. The aggregate is estimated at about 100,000. The whole number of deaths within that year, as given in the bills, was 97,306. Since this dreadful period, the plague has entirely ceased in London: a circumstance that must be regarded as the more remarkable, when it is considered how frequent had been its ravages for ages past, and when reference is had to the bills of mortality for the preceding part of this very century, when scarcely a year passed without some persons falling victims to the infection. For further particulars, see PLAGUE.

The most important event that ever happened in this metropolis, whether it be considered in reference to its immediate effects, or to its remote consequences, was the great Fire, which broke out in the morning of Sunday, September 2, 1666, and, being impelled by strong winds, raged with irresistible fury nearly four days and nights, nor was it entirely mastered till the fifth morning. The destructive extent of this conflagration was, perhaps, never exceeded in any part of the world, by any fire originating in accident. Within the walls it consumed almost five-sixths of the whole city; and without the walls, it cleared a space nearly as extensive as the one-sixth part left unburnt within. Scarcely a single building, that came within the range of the flames, was left standing. Public buildings, churches, and dwelling-houses were alike involved in one common fate; and, making a proper allowance for irregularities, it may fairly be stated, that the fire extended its ravages over a space of ground equal to an oblong square, measuring upwards of a mile in length, and half a mile in breadth. In the summary account of this vast devastation given in one of the inscriptions on the monument, and which was drawn up from the reports of the surveyors appointed after the fire, it is stated, that "the ruins of the city were 436 acres, *viz.* 373 acres within the walls, and 63 in the liberties of the city; that of the six-and-twenty wards it utterly destroyed fifteen, and left eight others shattered and half burnt; and that it consumed 400 streets, 13,200 dwelling-houses, 89 churches, besides chapels; four of the city gates, Guildhall, many public structures, hospitals, schools, libraries, and a vast number of stately edifices." The immense property destroyed in this dreadful conflagration could never be calculated with any tolerable degree of exactness; but according to the best estimations that have been made, the total value must have amounted to the immense sum of ten millions of pounds sterling. As soon as the general consternation had subsided, the rebuilding of the city became the first object of consideration; an act of parliament was passed for that purpose; and though all was not done that might have been, the city was principally rebuilt within little more than four years, and that in a style of far greater expence and regularity, and infinitely more commodious and healthful, than the ancient capital. In the system of tyranny and oppression which marked the reign of Charles II the city largely participated; having its ancient liberties and privileges invaded, and magistrates arbitrarily forced on the citizen at the pleasure of the king. Every principle of law and justice was violated; and in this humiliating state London continued till the revolution.

Annals of London from the Revolution in 1688, *to the present Time.*—In the first year of William and Mary, an act was passed, by which all proceedings of former reigns against the city charters were reversed, and all the rights and privileges of the citizens were fully re-established In 1692, during the king's absence in Holland, the queen borrowed 200,000*l.* of the city for the exigencies of government. In 1694, an infamous system of bribery was investigated by the house of commons, when it was proved, that a thousand guineas had been demanded and taken from the chamberlain of London by sir John Trevor the speaker, for forwarding the Orphan bill; in consequence of which he was expelled the house. In 1697, an act of parliament was passed for the suppression of the much abused privilege of sanctuary, heretofore attached to the following places, *viz.* the sanctuary in the Minories, Salisbury-court, White-friars, Ram-alley, and Mitre-court in Fleet-street; Fulwoods-rents in Holborn; Baldwin's-gardens in Gray's-inn-lane; the Savoy in the Strand; and Montague-close, Deadman's-place, the Clink, and the Mint, in Southwark. The year 1703 was remarkable for a dreadful storm of wind, which raged through the night of the 26th of November. The damage sustained by the city alone was estimated at two millions sterling; and in the suburbs the damage was proportionably great: the lead on the tops of several churches was rolled up like skins of parchment; and at Westminster-abbey, Christ's-hospital, St. Andrew's Holborn, and many other places, it was carried off from the buildings. The ships in the river were driven from their moorings; four hundred wherries were lost; more than sixty barges were driven foul of London-bridge, and as many more were sunk or staved above the bridge. At sea the destruction was immense; twelve men of war, with more than eighteen hundred men on board, were lost within sight of their own shore. The year 1709 was marked by a circumstance highly creditable to the humanity of the nation. The cruel depredations of the French in the palatinate compelled the inhabitants to

desert their country; twelve thousand, in the most forlorn condition, sought refuge in London: the queen, for some time, supported them out of her privy purse; she was afterwards assisted by the benevolence of her subjects, and 22,038*l.* was paid into the chamber of the city for the relief of these distressed fugitives, who were finally disposed of as colonists to Ireland and North America.

The increase in the population of the metropolis having occasioned a great insufficiency in places for divine worship, an act of parliament was passed in 1711 for erecting fifty new churches in and about London: the expence of which was defrayed by a small duty on coals brought into the port of London for about eight years. The year 1720 will ever be famous in the annals of London, from the destructive system of speculation and fraud which history has denominated the South Sea bubble; and which so completely infatuated the people, that they became the dupes of the most barefaced impositions. (See BUBBLE, in *Commerce*.) The directors of the South Sea Company, encouraged by the prevalent spirit of avaricious enterprise, proposed to the government to take into their fund all the debts of the nation, under the plausible pretext of a speedier redemption. The amount of the debts was 31,664,551*l.*; for the liberty of adding the whole of which to their capital stock, they offered to pay to the public the immense sum of 7,723,809*l.* This bait was too tempting to be refused; the plan received the sanction of parliament, and the directors were empowered to raise the ready money necessary for so great an undertaking, "by opening books of subscription, and granting annuities to such public creditors as were willing to exchange the security of the crown for that of the South Sea Company, with the advantage of sharing in the emoluments that might arise from their commerce." So much was the public mind impressed with the idea of rapid gain, that before the act received the royal assent, the company's stock rose to 319*l. per cent.*: it advanced so amazingly for three months, that books were then opened for a fresh subscription of four millions at 1000 *per cent.*; and such was the popular frenzy, that within a fortnight the new subscription was at 200 *per cent.* premium. Some alarm now prevailed: it had been whispered, that the directors and their friends had disposed of their own stock while the price was at the highest; and all confidence in the stability of their credit was destroyed. The confusion became general; every one was willing to sell, but no purchasers could be found, except at a vast reduction. Distraction and dismay spread through the city; the stock fell rapidly, and, before the end of the year, was reduced to 86 *per cent.* which was about its real value. The destruction to public and private credit, thus produced, was excessive: all trade was at a stand; and many of the most respectable merchants, goldsmiths, and bankers of London, who had unwisely lent large sums to the company, were obliged to abscond. A parliamentary investigation ensued; and the knavery of the directors was so apparent, that the greater part of their estates was confiscated for the benefit of those whom their villainy had ruined. The sum thus obtained amounted to 2,014,000*l.*

During the continuance of the infatuation which the South Sea delusion inspired into all classes of people, many other visionary projects were set on foot by speculators and gamblers; even chartered companies of established credit lent their countenance to schemes of impossible accomplishment: nearly two hundred subscription projects were afloat at one time. When the public confidence in the South Sea scheme was on the decline, the superior stability of the bank of England, East India, and African companies, was at once seen: Bank stock rose from 100 to 260; East India stock from 100 to 405; and African stock from 100 to 200. The shares in the London and Royal Exchange Assurance Companies also experienced a prodigious rise. See INSURANCE.

The close of the year 1729 was attended by a great mortality in London; the deaths within the bills of mortality in the course of the year amounting to almost 30,000. The pernicious habit of dram-drinking had become so general, and so many disorders had been occasioned, and crimes commited in consequence of it, that in the year 1736 the legislature found it necessary to prohibit the selling of Geneva, except under certain restrictions. Previous to this, the magistrates had ascertained that the number of gin-shops in London and Westminster was 7044, besides garrets and cellars where the baneful liquor was sold privately. So determined were the retailers to carry on their trade, that the utmost exertions of the police were required to enforce the act; and within two years, 12,000 persons were convicted and fined under its provisions.

The winter of 1739—40 was memorable from the occurrence of one of the most intense frosts ever known in this country, and which is recorded in our annals by the appellation of the Great Frost; it commenced on Christmas-day, and lasted till the 17th of February: above bridge the Thames was completely frozen over, and numerous booths were erected on it for selling liquors, &c. to the multitudes who daily flocked thither. Great improvements were now made in different parts of the metropolis; and convenience, health, and safety, were more generally attended to than they had previously been. Westminster bridge was finished and opened for public use in the year 1750; the houses upon London bridge were pulled down in 1756; and in the two succeeding years the bridge was put into a course of repair. In 1760 Black-friars' bridge was commenced; most of the city gates were taken down; and an act of parliament was obtained for making alterations in the avenues of the city and its liberties; some of which have been carried into effect at different periods, yet many others remain to be executed. In the year 1763, the recent peace with France, the resignation of Mr. Pitt, afterwards earl of Chatham, as premier, and other political occurrences, set the metropolis into a complete ferment. The conduct of administration was such, as to augment rather than obviate the prevailing discontents. Hence the ministry were assailed with political publications; in particular by a periodical paper called "The North Briton;" the writers of which, the principal of whom was John Wilkes, were determined to expose the measures of the then administration to the contempt they deserved. The forty-fifth number of this paper contained such severe reflections on the king's speech to parliament, that the ministry thought they had an opportunity to crush their avowed enemy. Mr. Wilkes was apprehended and committed to the Tower under an illegal warrant, signed by the principal secretary of state; but the case being argued in the court of Common Pleas, before lord chief justice Pratt, the court directed him to be discharged. Mr. Wilkes brought actions against the earl of Halifax, secretary of state, for issuing the warrant, and against Mr. Wood, under-secretary, and obtained verdicts with damages; 4000*l.* from the former, and 1000*l.* from the latter. Shortly after his release, Mr. Wilkes established a printing-press in his own house, and republished all the numbers of the obnoxious paper. This provoked the ministry so highly, that an information was filed against him. The "North Briton, No. 45," was voted by the house of commons to be a seditious libel, and ordered to be burnt by the common hangman. Mr. Wilkes was expelled the house;

and though he retired to France, his trial was brought on in his abfence, when he was found guilty of republiſhing the libel, and was confequently outlawed. Four years afterwards he returned to England, his outlawry was reverfed, and he was fentenced to two years imprifonment; during which he was elected an alderman of London, and knight of the ſhire for Middlefex.

In the year 1780, from a cauſe apparently harmleſs, a petition to parliament from the Proteſtant Aſſociation, aroſe an inſurrection, compoſed chiefly of the loweſt of the people, which for a week bore the moſt alarming appearance; the priſons of Newgate, the King's Bench, and the Fleet were burnt and the priſoners ſet at liberty, and moſt of them joined the inſurgents. The Popiſh chapels, and a great number of private houſes of Catholics, were ſet on fire: and thirty ſix fires were ſeen blazing at one time in various parts of the metropolis. Military interference became abſolutely neceſſary, when many of the rioters were killed; 135 were brought to trial, of whom 59 were convicted, and upwards of 20 of the moſt active were executed in various parts of the town, but immediately contiguous to the ſcenes of their reſpective depredations.

During the year 1792, and the two following years, the metropolis was greatly agitated by political contention; many aſſociations were formed for the purpoſe of obtaining a more pure and equal repreſentation of the people. The two principal of theſe aſſociations, *viz.* the Friends of the People, and the Correſponding Society, held their meetings in London. Their avowed object was parliamentary reform; but they were ſtigmatized by their enemies with the appellations of Republicans and Levellers. Some of the moſt active and powerful leaders of theſe aſſociations were at length arreſted, and tried for high treaſon, but after a long inveſtigation all were acquitted. Other perſons, among whom was Thomas Paine, were proſecuted for ſedition, and ſome were impriſoned. Paine was pronounced guilty of writing and publiſhing the ſecond part of the Rights of Man, which was declared ſeditious, and the author having left the kingdom, was outlawed. The numerous clubs, debating ſocieties, and political aſſociations formed in the metropolis ſoon after the revolution in France, and during the early ſtages of the war againſt that country, conſtitute a prominent epoch in the hiſtory of the metropolis. The country was hurried on to the very brink of revolution; but this great criſis was prevented by the vigilant, powerful, and determined conduct of the Pitt adminiſtration. An Alien act was paſſed in 1793, the Habeas Corpus act was ſuſpended in the next year; and various arbitrary and oppreſſive meaſures were adopted by the miniſtry to preſerve public tranquillity, but at the ſame time abridge the rights of the Britiſh ſubjects.

The year 1797 was diſtinguiſhed by the ſtoppage of bank payments in ſpecie, as the government had employed nearly all the current coin in remittances to the emperor of Germany and to other foreign powers. An act of parliament was now paſſed to allow the bank to iſſue notes under five pounds. At the commencement of 1798 a numerous meeting of the bankers, merchants, and traders of London, was held in the Royal Exchange for the purpoſe of raiſing a voluntary ſubſcription for the public ſervice. In the courſe of four days the common council alone ſubſcribed 10,000*l.*, 200,000*l.* was ſubſcribed by the bank, conſiderable ſums were given by other public companies, and 20,000*l.* was advanced by his majeſty. The miniſter eſtimated this ſubſcription at one million and a half, but the total amount was more than two millions of money. Continued threats of invaſion from France induced the miniſter to adopt ſome new mode of defence; and ſeveral armed aſſociations were formed by different pariſhes and companies in the metropolis. On the 4th of June, 1799, all theſe volunteers were aſſembled in Hyde Park, and reviewed by his majeſty, the princes, &c. The total number under arms was 8989, of which 1008 were cavalry. On the 21ſt of the ſame month, a ſtill greater number of volunteers was diſperſed through the ſtreets, ſquares, and ſuburbs of the metropolis, to be inſpected again by the king, and a numerous retinue of princes, dukes, &c. It is ſtated, that 12,208 volunteers were then drawn out under arms. A ſimilar review of the volunteers to the former, took place on the 4th of June 1800. On the ratification of preliminaries of peace in October, 1801, the metropolis was brilliantly illuminated, and all claſſes of people teſtified great joy at the event. The definitive treaty was ſigned on the 27th of the following month, and the illuminations throughout London were now ſingularly ſplendid and general. A war again broke out, and an act of parliament was paſſed to enable his majeſty to arm the people *en maſſe.* Other acts for increaſing the military force of the country were alſo paſſed. The cities of London and Weſtminſter, and pariſhes immediately adjacent, raiſed a volunteer force amounting to 27,077 men. A patriotic fund was eſtabliſhed in London in July 1803, and before the end of Auguſt more than 152,000*l.* were ſubſcribed; towards which the city, in its corporate capacity, gave 2500*l.* The ſucceſſive deaths of lord Nelſon, Mr. Pitt, and Mr. Fox, produced great ſenſation in the metropolis, and many changes in the legiſlative officers. Covent Garden theatre and ſeveral contiguous houſes were conſumed by fire in September 1808; another fire in January 1809, deſtroyed part of the king's palace at St. James's, and a third fire, in February of the ſame year, conſumed the whole of Drury-lane theatre. The October of 1809 is memorable in the annals of London, for the circumſtance of his majeſty's entrance into the fiftieth year of his reign, and the loyal rejoicings, or public manifeſtations of loyalty that were diſplayed on the occaſion. The memorable and unpropitious expedition to Walcheren, the theatrical riots at Covent Garden theatre, the inveſtigation, before the houſe of commons, relating to the duke of York and a noted proſtitute of the name of Clarke, the arreſt and impriſonment of ſir Francis Burdett, a member of the houſe of commons, are all memorable events in the local hiſtory of London, and are entitled to particular narration and expoſition in a publication devoted to the topography of the metropolis. In Brayley's Survey, already referred to, theſe ſubjects are particularized and elucidated. It is conjectured that within the laſt forty years, 40,000 new houſes at leaſt have been erected in London and its connected environs, and that theſe afford habitation for nearly 200,000 new inhabitants. In July, 1794, a fire broke out in Radcliffe highway, and conſumed 630 houſes, with much other property. Many of the inhabitants fixed tents in the open fields, where they lived for ſeveral weeks till new houſes were erected.

Hiſtory of the Commerce of London.—

"Then Commerce brought into the public walk
The buſy Merchant; the big Warehouſe built;
Rais'd the ſtrong Crane; choak'd up the loaded Street
With foreign Plenty; and thy Stream, O Thames,
Large, gentle, deep, majeſtic king of floods!
Choſe for his grand reſort." Thomſon.

London is univerſally acknowledged to be the firſt commercial, as well as the firſt manufacturing city in the world. Conſidering, therefore, the intimate connection that ſubſiſts between its trading proſperity and the general intereſts of the empire; the ſubject of this ſection cannot fail to be

highly interesting and important. To trace the steps by which London has risen to its present opulence and grandeur, is in fact to develope the sources of that distinguished rank which England now holds among the nations of the earth.

London was, doubtless, a place of considerable trade at a very early period. Tacitus speaks of it as the *nobile emporium* of his time; the great resort of merchants, and though not a colony, famous for its commercial intercourse. After this, little is known of it, in respect to trade, until the close of the second century of the Christian era, when it is again mentioned as having become "a great and wealthy city." In the year 359, it is said of England, that its "commerce was so extended, that 800 vessels were employed in the port of London for exportation of corn only." Three centuries afterwards Bede styles it "an emporium for many nations repairing to it by land and sea." Fitz-Stephen, who lived in the reign of Henry II. says, that "no city in the world exports its merchandize to such a distance as London;" but does not inform us what goods were exported, or to what countries they were carried. Among the imports, however, he enumerates gold, spices, and frankincense from Arabia; precious stones from India; and palm-oil from Bagdad. But it seems more reasonable to suppose these were obtained through the medium of the trading cities of Italy, than by direct commerce to the respective places. William of Malmsbury, who likewise lived about this period, calls "London a noble city, renowned for the opulence of its citizens," and "filled with merchandize brought by the merchants of all countries." The same author adds, "that in case of scarcity of corn in other parts of England, it is a granary, where it may be bought cheaper than any where else." Thus it will be perceived, that even in the infancy of European commerce, and at a time when ignorance and barbarism clouded almost every portion of the world, this city had made no inconsiderable progress towards its present celebrity and importance.

In the year 1220, the merchants of Cologne, in Germany, probably in consequence of an invitation from king John in 1203, established a hall or factory in London, which shortly after became the general factory of all the German merchants resident in the city. Not long subsequent to this period, *viz.* in 1245, sea coal "carbone maris," is mentioned among the articles of inquisition into trespasses committed in the king's forests. Hence it may reasonably be inferred, that coal was not only known and wrought before this time, but actually formed a part of the imports of London. Sea-coal lane, in this city, was certainly so named as early as the year 1253, and according to Stow, received this appellation from lime being burnt there with sea-coal.

The close of the thirteenth century appears to have been a remarkable era in the commercial history of London. In 1296, the company of merchant-adventurers was first incorporated by Edward I. The Hansards, or Hanse merchants, also received considerable privileges about the same time. In the year 1498, when all direct commerce with the Netherlands was suspended, this body obtained very great advantages over the merchant adventurers by importation of vast quantities of those articles, through the medium of the Hanse towns, which before had come directly from the Netherlands, where the trade of the latter company had been chiefly established. In consequence of these circumstances, the warehouses of the merchants were attacked and rifled by the mob; but the offenders were soon suppressed, and many of them punished.

In the year 1504, all the ancient privileges of the Hanse, or as they were likewise called, Steel-yard merchants, were confirmed to them by statute, and all the previous acts which had been made in derogation of them were annulled. A similar charter was also obtained by the English merchants "trading in woollen cloths of all kinds to the Netherlands," in which they are for the first time styled the "Fellowship of merchant-adventurers of England." This act strictly prohibited the Steel-yard association from interfering with their trade, by carrying cloths to any of their settlements in the Low Countries. Notwithstanding these unfavourable clauses, however, the Hanse-merchants seem to have engrossed the chief trade of the city. Grievous accusations were consequently made against them, for their proceedings were considered as tending to ruin the commerce of the native English. The city of London at length instituted an action, in the Star-chamber, against them, the object of which was to deprive them of their privileges as a body. Accordingly, in the year 1597, a decree was obtained, annulling their association, and ordering them, under severe penalties, to quit the kingdom. See Hanse *Towns*.

But to return: it may be proper to remark, that during the contentions between the houses of York and Lancaster, the commerce of London was very considerably retarded. In the reign of Henry VII. it again began to make rapid progress. Still, however, if credit is to be given to Wheeler's "Treatise on Commerce," published in 1601, the trade of this city must have been very low indeed, even as late as the year 1539; for that author expressly avers, that sixty years before he wrote, there were not above four merchant vessels exceeding 120 tons burthen in the river Thames. Nor would it appear that they had increased much in the next reign, if we are to believe the report of a London merchant, who, in a letter to sir William Cecil says, that there is not a city in Europe "having the occupying that London hath, so slenderly provided with ships."

Notwithstanding these complaints, however, it is undoubtedly a fact, that a spirit of enterprise was very general among the merchants about this period. For, in 1553, we find a great geographical and mercantile discovery made by a company, consisting of 240 shareholders, instituted for the purpose of prosecuting discoveries under the direction of Sebastian Cabot, a merchant of Bristol. (See Cabot, Sebastian.) This association having fitted out three ships, one of them accidentally fell into the bay of St. Nicholas, in the White seas, and landing at Archangel, obtained from the czar of Russia peculiar privileges of trade with the subjects of his dominions. Within a few years after, the London merchants had also factors settled at the Canaries. The Russia or Muscovy merchants were incorporated in the reign of Philip and Mary, and had their charter subsequently confirmed by Elizabeth, in her eighth year. This princess, likewise, obtained an exclusive grant to the English of the whole foreign commerce of that extensive empire, which they continued to enjoy for a considerable period. About this time the civil dissentions in Flanders began, upon which a vast number of families from the Netherlands flocked to London, and brought over with them their trade and riches. This great addition to the population of the city, and the consequent increase of its commerce soon after, led to the erection of the Royal Exchange, by the celebrated sir Thomas Gresham, in the years 1566 and 1567. (See Royal *Exchange*.) Previous to this the merchants were accustomed to meet twice every day in Lombard-street, without any other refuge from the severities of the weather but what the neighbouring shops might occasionally afford. In 1579, the Levant, or Turkey Company, was established, as was also the Eastland Company; both of which still exist, but the former only retains any degree of importance. On the

31st of December, 1600, the queen granted the first patent to the East India Company. Their stock then amounted to 72,000*l.* and with this sum the company was enabled to fit out four ships under the command of James Lancaster. The adventure proving successful, the company continued its exertions, and hence has arisen the most splendid and powerful mercantile association that probably ever existed in the world. (See COMPANY, *East India.*) Assurance and insurance companies were now established in London. An act was passed in 1601 for regulating the business of assurance, and a standing commission of merchants appointed to meet weekly "at the office of insurance on the west side of the Royal Exchange." (See INSURANCE *Companies.*) The company of Spanish merchants were likewise among the number of those incorporated by Elizabeth, so that the reign of that princess may be justly said to form a grand era in the commercial history of this metropolis.

In the reign of James I. the progress of the foreign trade was rapidly increased. Tobacco, which had first been introduced in 1565, now became a considerable article of import. (See TOBACCO.) The tonnage and number of the shipping in the port of London were greatly augmented about this time. Many of the patents granted by Elizabeth were annulled, and the trade thrown open. Howe, speaking of the foreign commerce of this city in the year 1614, says, "London, at this day, is one of the best governed, most richest, and flourishing cities in Europe; plenteously abounding in free trade and commerce with all nations; richly stored with gold, silver, pearl, spice, pepper, and many other *strange* commodities from both Indies; oyles from Candy, Cyprus, and other places under the Turk's dominion; strong wines, sweet fruits, sugar, and spice, from Grecia, Venice, Spayne, Barbaria, the islands and other places lately discovered and known; drugs from Egypt, Arabia, India, and divers other places; silks from Persia, Spayne, China, Italy, &c.; fine linen from Germany, Flanders, Holland, Artois, and Hanault; wax, flax, pitch, tarre, mastes, cables, and honey, from Denmark, Poland, Swethland, Russia, and other northern countries; and the superfluity in abundance of French and Rhenish wines, the immeasurable and incomparable increase of all which coming into this city, and the encrease of houses and inhabitants within the terme and compasse of fifty years, is such and so great, as were there not now two-thirds of the people yet living, having been eye-witnesses of the premises and bookes of the custom-house, which remain extant, the truth and difference of all things afore-mentioned were not to be justified and believed." Howe's edition of Stow's Annals of England, p. 868.

Among the circumstances which occasioned the vast increase of trade during this reign, may be reckoned the colonization of America and the West India islands. The new discoveries, likewise, which were every day made in different quarters of the world, no doubt had a powerful effect in stimulating numbers of speculating persons to commercial exertion and adventure.

During the peaceful years of Charles I. the commerce of this metropolis still continued to make rapid progress; and though the civil wars, for a time, had a very contrary operation, yet in the end they certainly proved beneficial. The energies of the mind were more awakened; the habits of thinking and modes of action, which then became general, taught man to feel his dignity as an individual; the different ranks of society were more closely drawn together; the exertions of industry were better directed; and the means of acquiring wealth greatly augmented. The injurious tendency of monopolies was eminently counteracted; for, though never abolished by any direct statute, men, regardless of the prerogative whence they were derived, gradually invaded the privileges they conferred, and commerce was increased by the increase of liberty.

The augmented commerce of the port of London, in this reign, may in some measure be estimated by the quota of ship-money, which Charles I. imposed on the city in 1634. By one writ, the citizens were ordered to fit out and equip, at their own charge, for 26 weeks, one ship of 900 tons and 930 men, one of 800 tons and 260 men, four of 500 tons each and 200 men, and one of 300 tons and 150 men. Next year they were commanded to provide two ships of 800 tons and 320 men each. About this time, or at least very shortly before, prices-current were first printed. In 1635, an order was issued by the king in council to the "postmaster of England for foreign parts," requiring him to open a regular communication, by running post between the metropolis and Edinburgh, Ireland, and a variety of other places.

Previous to the year 1640, it was usual for the merchants to deposit their cash in the Tower mint; but this deposit now lost all its credit by the ill-advised measure of a forced loan, which the king thought proper to make. The merchants, in consequence, found themselves obliged to trust their money to their apprentices and clerks. The circumstances of the times and opportunity holding forth great inducements to frauds, many masters lost at once both their servants and their money. Some remedy became necessary; and the merchants now began to lodge cash in the hands of the goldsmiths, whom they also commissioned to receive and to pay for them. Thus originated the practice of banking: for the goldsmiths, soon perceiving the advantages that might be derived from disposable capital, began to allow a regular interest for all sums committed to their care; and, at the same time, they commenced the discounting of merchants' bills at a yet superior interest than what they paid. (See BANK and BANKING.) In 1651 the celebrated navigation act was passed, the wise provisions of which have no doubt contributed much to promote our naval and commercial greatness. This same year, coffee was introduced into London by a Turkey-merchant named Edwards. (See COFFEE.) The sugar trade was now likewise established; and upwards of 20,000 cloths were sent annually to Turkey, in return for the commodities of that country.

The plague, which made such dreadful havoc among the citizens in 1665, almost wholly suspended the commerce of London; insomuch that scarcely a single foreign vessel entered the port for the space of three years. The great fire, which happened in 1666, likewise occasioned incalculable loss to numbers of the most opulent merchants in the city. Notwithstanding these disastrous events, however, the spirit of the survivors, so far from sinking, was roused to uncommon exertions. In the course of a few years, the city rose from its ashes with greater magnificence and splendour. India muslins were first worn in 1670, and soon became prevalent. In this year also was the Hudson's Bay Company established, with very extensive powers. The Greenland Fishing Company was incorporated in the year 1693; and the institution of the Bank of England rendered the succeeding one justly memorable in the commercial annals of London. See COMPANY.

The commerce to the East Indies having become vastly enlarged, and many disputes arising relative to exclusive trade, a new joint stock company was incorporated in London, in the year 1698, by the name of "The English Company trading to the East Indies." The existence of two rival companies having the same privileges, however,

ſoon gave birth to numerous abſurdities and contradictory queſtions of right. Theſe circumſtances, and ſome others which it is unneceſſary to detail in this place, eventually produced the conſolidation of both into one, in the firſt and ſeventh years of queen Anne, by the title of "The United Company of Merchants trading to the Eaſt Indies." See COMPANIES, *Engliſh*, the *Eaſt India*, vol. ix. for a full account of this eſtabliſhment.

The number of veſſels belonging to the port of London, as appears from returns made to circular letters from the commiſſioners of the cuſtoms, amounted, in 1701, to 560; carrying 84,882 tons and 10,065 men. In 1710 the cuſtoms of this city are ſtated at 1,268,095*l.*, and thoſe of all the out-ports only at 346,081*l.*, which is more than three and a half to one. The following year beheld the incorporation of the South Sea Company, afterwards ſo baneful in its effects to numerous individuals, and ſo generally hurtful to the commercial enterpriſe of the country at large. The Royal Exchange Aſſurance and the London Aſſurance Companies were chartered about the ſame time.

During the reign of George I. the trade of London made very little, if any, progreſs. The failure of the South Sea ſcheme, the rebellion in Scotland, and the Spaniſh war, were the combined cauſes which operated to produce its retardation. In the year 1732, however, commerce began again to revive; but its advances continued comparatively ſlow, till the peace of Aix-la-Chapelle in 1748, after which it extended with uncommon rapidity. The next conſiderable check it ſuſtained was the reſult of the American war. No ſooner, however, was peace ſigned than it proceeded with renewed vigour. The grievous conſequences which many perſons apprehended to our trade, from the declaration of the independance of the United States, were only imaginary. For, even ſo ſoon after that event as the year 1784, the value of exports to America only had increaſed to 3,397,500*l.*, ſomewhat more than 332,000*l.* above the greateſt amount in any one year before the war. The net ſum of duties levied in the port of London, and paid into the exchequer this year, aroſe to the vaſt ſum of 4,472,091*l.* 13*s.* 3*d.* From this period to 1793, when the French revolution began, the commerce of London continued uniformly increaſing. In that year, however, the value of exports was upwards of two millions leſs than in the preceding year; though the imports ſcarcely ſuffered any diminution. Numerous bankruptcies conſequently took place; but the timely interference of the legiſlature, and the voting of exchequer bills to the amount of 5,000,000*l.* for the uſe of ſuch perſons as could give ſufficient ſecurity, ſoon checked the growing diſtreſs.

In the courſe of the three ſucceeding years, the appearance of things was entirely altered. In 1796 the exports of London amounted in value to 18,410,499*l.* 17*s.* 9*d.*, and the imports to 14,719,466*l.* 15*s.* 7*d.* The number of Britiſh ſhips that entered the port amounted to 2007, carrying 436,843 tons; and 2169 foreign veſſels, carrying 287,142 tons. The total entering coaſtwiſe was 11,176, including repeated voyages, which made a tonnage of 1,059,915. The following year, ſome alarm was ſpread among the merchants by the ſtoppage of the bank payments *in ſpecie*; but, through the intervention of parliament, confidence was ſoon reſtored. The net amount of the cuſtoms was 3,950,608*l.* In 1798 the importations of ſugars and rum far exceeded thoſe of any preceding year, as did likewiſe the revenue of the cuſtoms, which amounted to the ſum of 5,321,187*l.* 7*s.* 3*d.* In 1799 it had increaſed to 7,226,353*l.* 0*s.* 1*d.*, Weſt India $4\frac{1}{2}$ *per cent.* duty included; but next year fell to 6,468,655*l.* 13*s.* 7*d.* The *official* value of the imports, in 1800, was 18,843,172*l.* 2*s.* 10*d.*; and of the exports, 25,428,922*l.* 16*s.* 7*d.* Their *real* value amounted in all to 68,000,000*l.*, nearly two-thirds of the value of the whole trade of the kingdom. The number of veſſels belonging to the port in that year appeared, from official documents laid before parliament, to be 2666, carrying 568,262 tons, and 41,402 men. Comparing this number with the number returned in the beginning of the laſt century, the increaſe will be ſeen to be aſtoniſhing. On the quantity of tonnage, it is nearly in the proportion of ſix to one; and on the amount of men and ſhips, as upwards of four to one. The Eaſt India Company's ſhips alone carry more burthen, by 21,166 tons, than all the veſſels of London did a hundred years ago. The average number of ſhips in the Thames and docks is 1100, together with 3000 barges employed in lading and unlading them, 2288 ſmall craft engaged in the inland trade, and 3000 wherries for the accommodation of paſſengers; 12,000 revenue officers are conſtantly on duty in different parts of the river; 4000 labourers are employed in lading and unlading, and 8000 watermen navigate the wherries and craft. See DOCKS and COMPANIES.

The *Port of London*, as actually occupied by ſhipping, extends from London bridge to Deptford, being a diſtance of nearly four miles, and from four to five hundred yards in average breadth. It may be deſcribed as conſiſting of four diviſions, called the Upper, Middle, and Lower Pools, and the ſpace between Limehouſe and Deptford: the Upper Pool extends from London bridge to Union Hole, about 1600 yards; the Middle Pool, from thence to Wapping New Stairs, 700 yards; the Lower Pool from the latter place to Horſe-ferry Tier, near Limehouſe, 1800 yards; and the ſpace below to Deptford about 2700 yards. When the houſe of commons commenced an inveſtigation reſpecting the port of London, the land accommodations were found to conſiſt of only the legal quays and the ſufferance wharfs. The former were appointed in the year 1558, under a commiſſion from the court of exchequer, authorized by an act of the firſt year of Elizabeth, for the excluſive landing of goods, ſubject to duty: they occupy the north bank of the river Thames, with ſome interruptions, from London bridge to the weſtern extremity of Tower ditch; the whole frontage meaſuring about 1464 feet. Till of late years theſe quays conſtituted the whole legal accommodation for the prodigious ſhipping trade of London; though from the increaſed ſize and tonnage of merchant veſſels, &c. the depth of the river in this part was found too ſhallow to admit of that ſpeedy clearance which the trading and mercantile intereſts require. The commiſſioners of the cuſtoms, therefore, occaſionally permitted the uſe of other landing places, which were thence called Sufferance wharfs, and of which five were ſituated on the north ſide of the river, between the Tower and Hermitage Dock, and eighteen on the oppoſite ſide: the whole having a frontage of 3676 feet. Notwithſtanding theſe additional conveniences, the whole number of quays was ſtill very far from poſſeſſing ſufficient accommodation for the increaſed trade; and more eſpecially in times of war, when large fleets of merchantmen arrive at once. The numerous evils ariſing from this want of a ſufficient ſpace for ſhipping and landing goods, and among which, the monopoly thrown into the hands of the few legal quays was not the leaſt, were for many years ſubjects of vexation and complaint. So long ago as 1674, the merchants of London petitioned the houſe of commons for redreſs againſt a combination, which the whole body of wharfingers had entered into; and, in the year 1711, when the tonnage of the veſſels belonging to London did not amount to one-third

part of what it does now, the commissioners of the customs recommended to government to make a legal quay at Bridge yard, on the south side of the river; but it was never executed. About the year 1762, the court of exchequer directed a part of the Tower wharf to be converted into a legal quay; but this plan was relinquished. The construction of Wet docks had been recommended as the best expedient for obviating the vast loss and embarrassment arising from the encumbered state of the quays and wharfs, and from the immense crowding of the vessels on the river; and through the various schemes which were about this time offered for the purpose, &c. the house of commons was induced to appoint a committee; the business of which has been to inquire into the best mode of improving the port, and render it completely adequate to the present and probable commerce of London. The most skilful engineers and surveyors have been employed; whose reports, plans, &c. with the opinions and statements of various merchants and other persons, have been printed by order of the house of commons. These reports constitute several volumes in folio; and are peculiarly interesting and curious. Sir Frederic Eden published a pamphlet on the same subject, entitled "Porto-Bello, or a plan for the improvement of the port and city of London; illustrated by plates," 8vo. 1798. For a particular account of the various branches of commerce, commercial companies, and other objects connected with the same, the reader is referred to the words DOCKS, COMPANIES, EAST INDIA *Trade*, WEST INDIA *Trade*.

Custom House.—On the north bank of the Thames, west of the Tower, is a large building, appropriated to such officers, clerks, tide-waiters, &c. as are immediately concerned in received the king's duties on the exports and imports of commerce. The present building was erected in 1718, on the scite of another which had been destroyed by fire. It is 260 feet in front; and when erected was deemed amply sufficient for its destination. It has proved, however, very inadequate to the increased customs and business of the port; and to the vast commerce of London. After various surveys and reports made on the subject, it has been recently determined by the commissioners of the customs, that a new custom-house shall be erected, upon such a scale, and provided with such numerous and various accommodations, as to meet the exigencies and demands of government. Mr. David Laing, architect to the customs, having furnished designs for a new edifice, and the same being approved, it is intended to proceed with the building immediately. The scite is from the western side of the present edifice to Billingsgate quay; and its whole extent will constitute a range of 480 by 96 feet. In the centre is to be the long room, of 190 feet by 67. The whole building will accommodate 650 officers and clerks, the number employed here; also 1050 tide-waiters, and other inferior servants. The lower floor is to consist of bondage vaults, over which are to be numerous apartments for officers and offices; and above these are to be several others, with the long room already noticed. The water front is to be of stone, with Ionic columns at each wing, and the centre will be crowned with a large dome over the long room, with sky-lights and ventilators. It is but justice to say that the designs are creditable to the taste and science of the architect. The quay in front of the building is to be enlarged by filling up a part of the river. A new wall and quay are to be formed from the Tower to Billingsgate wharf, and numerous improvements will be made in the contiguous streets and lanes. The river, at this place, is about 20 feet deep at high water mark. The business of the customs is managed by nine commissioners, whose jurisdiction extends over all the ports of England.

Manufactures of London.—London has long been celebrated for its manufactures as well as for its commerce. In the year 1327 the Skinners were a very numerous and rich class of citizens, manufacturing "sables, lucerns, and other rich furs." Cloth-workers of different kinds were also noted for the excellence of their goods. In 1556 a manufactory for the finer sort of glasses was established in Crutched Friars, and flint glass, not exceeded by that of Venice, was at the same time made at the Savoy. About five years subsequent the manufacture of knit stockings was introduced by one William Rider, an apprentice in London, who happening to see a pair from Mantua at the house of an Italian, made another exactly similar to them, which he presented to William earl of Pembroke. (See HOSE and STOCKINGS.) A manufacture of knives was shortly after begun by Thomas Matthews of Fleet-street, and this has ever since been a flourishing trade. Silk stockings were first made in England in the reign of queen Elizabeth. In the fourth year of that princess, "John Rose, dwelling in Bridewell, devised and made an instrument with wyer stringes, called the Bandora, and he left a son far excelling him in making bandoras, viol de gamboles, and other instruments." Coaches were introduced in 1564, and in less than 20 years became an article of great manufacture. The following year the manufacture of pins was established, and shortly after that of needles. The making of "earthen furnaces, earthen fire-pots, and earthen ovens, transportable," began about the tenth year of Elizabeth, one Richard Dyer, an Englishman, having brought the art from Spain. Women's masks, busks, muffs, fans, bodkins, and periwigs were introduced and made in London shortly after the massacre at Paris in the year 1572, and in 1577 pocket watches were brought from Nuremberg in Germany, and the manufacture of them almost immediately commenced. In the reign of Charles I. saltpetre was made in such quantity, as not only to supply all England, but the greater part of the continent. The manufactures of silk had likewise become extremely prevalent, as well as the manufacture of various silver articles. The printing of calicoes commenced here in 1676, and about the same time the weavers' loom was introduced from Holland. The revocation of the edict of Nantes in 1685, having driven many industrious Frenchmen from their native land, a considerable number came over to England and settled in Spitalfields. By them several of our manufactures, but particularly that of silk, were greatly improved, and many others introduced. Since then the productions of London have greatly increased both in extent and value. They now consist chiefly of fine goods, and articles of elegant use, brought to the greatest perfection, such as cutlery, jewellery, articles of gold and silver, japan ware, cut glass, books, cabinet work, and gentlemen's carriages; together with such particular articles as require a metropolis, or a port, or great mart for their consumption, export, or sale; *viz.* porter, English wines, vinegar, refined sugar, soap, &c. The silk manufactories of Spitalfields, Shoreditch, and Bethnal-green parishes alone employ upwards of 7000 persons. In Clerkenwell a like number are engaged in the different branches of watch-making. Coach builders and harness makers are very numerous, and have brought their respective works to a higher degree of perfection and elegance than any in the world. Intimately connected with this subject is the

Trade of London, which is vast, various, and of extensive effect. It may be divided into the wholesale and retail business; for these are different, and under different systems of management. The great number and variety of shops that are dispersed over the metropolis, the diversity, richness, and multitude of articles displayed for sale, and the great con-

course of persons immediately and collaterally dependent on, and intimately connected with the same, are calculated to excite the astonishment of foreigners, and of persons who have not made inquiries into the subject. The wholesale trade is mostly carried on in the city, and in the vicinity of the river, where large warehouses and counting-houses are established. The retail trade is dispersed through all the public streets: where spacious and handsome shops are opened for the display of all the necessaries, as well as all the luxuries of life. The shop-keepers of London are mostly an active, industrious, and respectable class of society: many of them are wealthy, and frequently retire from business in advanced age, with competence, or fortunes. Among the most modern shop establishments upon a large scale, are those appropriated to books and prints. Within the last 50 years, these have been prodigiously increased: and it would greatly astonish Addison, Johnson, or sir Joshua Reynolds, could they revisit London in 1812, and take a review of the change that has been produced since the time they lived, in the quantity and quality of literary productions, and in works of art. The regular, continued and perpetual intercourse that subsists between London and all parts of the kingdom, by coaches, waggons, barges, &c. constitutes another and strongly marked feature.

Provisions, &c. used in London.—An immense population will require a large and systematic supply of provisions; and in this respect, no city in the world can be better accommodated; laws, custom, and open competition are all conducive to public advantage.

Animal Food. The number of oxen annually consumed in London is estimated at 110,000; of sheep, 770,000; of lambs, 250,000; of calves, 250,000; of hogs and pigs, 200,000; besides animals of other kinds. In speaking of the consumption of animal food in London, it is not sufficient to notice merely the number of animals brought to market; for their size and fine condition should also be considered in forming a proper criterion. The increased consumption of the metropolis, from its accumulating population, may be estimated from the following average of the number sold annually in Smithfield.

				Oxen.	Sheep.
From	1750	to	1758	75,331	623,091
	1759	—	1767	83,432	615,328
	1768	—	1776	89,362	627,805
	1777	—	1785	99,285	687,588
	1786	—	1794	108,075	707,456

It is not only in number but in weight that there has been an astonishing increase; this has arisen from the improvements in breeding that have taken place in the course of the last century. About the year 1700, the average weight of an ox, killed for the London market, was 370lbs.; of a calf, 50lbs.; of a sheep, 28lbs.; of a lamb, 18lbs.; whereas the average weight at present is, of oxen, 800lbs. each; of calves, 140lbs. each; of sheep, 80lbs. each; and of lambs, 50lbs. each. The total value of butchers' meat sold in Smithfield is calculated to amount to 7,000,000*l.* *per annum.*

Milk.—The quantity of this article consumed in London surprizes foreigners; and yet few persons have even a suspicion of the amount, which is not less than 6,980,000 gallons annually. The number of cows kept for this supply is said to be 8500; the sum paid by the retailers of milk to the cow-keepers is stated at 317,400*l.* annually, on which the retailers lay an advance of *cent. per cent.*, making the cost to the inhabitants 634,000*l.* Not content with this profit, the retailers add water to the milk, to the extent, on an average, of a sixth part. Though the cow-keepers do not themselves adulterate the milk, (it being the custom for the retailer to contract for the milk of a certain number of cows, to be milked by his own people,) yet they are not wholly to be acquitted of the guilt; for in many of the milk-rooms where the milk is measured to the retailer, pumps are erected for the express purpose of furnishing water for the adulteration, which is openly performed in the presence of any person who happens to be on the spot. See Milk.

Vegetables and Fruit.—There are at least 10,000 acres of ground near the metropolis, cultivated wholly for vegetables, and about 3000 acres for fruit. The sum paid at market annually is about 645,000*l.* for vegetables, and about 400,000*l.* for fruit; independently of the advance of the retailers, which, on an average, is more than 200*l.* *per cent.*, making the entire cost for the London supply upwards of 3,000,000*l.*

Wheat, coals, &c.—The annual consumption of wheat in London is, at least, 900,000 quarters, each containing eight Winchester bushels; of coals 800,000 chaldron, 36 bushels, or a ton and half to each chaldron; of ale and porter 2,000,000 barrels, of 36 gallons each; spirituous liquors and compounds 11,146,782 gallons; wine 65,000 pipes; butter about 21,265,000lbs.; and cheese, 25,500,000. The quantity of porter brewed from July 5, 1809, to July 5, 1810, by two of the principal brewers, was, by Barclay, Perkins, and Co. 235,053 barrels, and by Meux, Reid, and Co. 211,009. (See Porter.) The quantity of fish consumed in the metropolis is comparatively small, on account of the high price which it generally bears; and this appears to be the most striking defect in the supply of the capital, when it is considered that the rivers of the kingdom, and the seas which surround it, must afford such an amazing quantity. There are, on an average, annually brought to Billingsgate market 2500 cargoes of fish, of 40 tons each, and about 20,000 tons by land-carriage, in the whole 120,000 tons. The supply of poultry being inadequate to a general consumption, and the price consequently exorbitant, this article is confined to the tables of the wealthy, and the annual value does not exceed 60,000*l.* Game is not publicly sold, yet a considerable quantity, by presents, and even by clandestine sale, is consumed by the middling classes. Venison is sold, chiefly by pastry-cooks, at a moderate rate; but the chief consumption, which is considerable, is amongst the proprietors of deer parks.

Markets, &c.—London contains 15 flesh markets, one for live cattle, sheep, horses, &c. and 25 for corn, coals, hay, vegetables, &c. Of these the principal are, at Smithfield, for bullocks, sheep, horses, swine, hay, straw, &c.; Leadenhall, for butchers' meat, wool, hides, &c.; Billingsgate, for fish; Covent garden and Fleet, for fruit and vegetables; Newgate, Newport, Carnaby, and Clare markets, for butchers' meat, &c.; the corn market in Mark-lane: in Thames street is a coal exchange. London has only one annual fair, which is held in Smithfield, and continues for three days. It is mostly devoted to objects of amusement, such as shows, exhibitions of beasts, birds, slights of hand, and the very lowest species of diversion. Hence it is mostly frequented by the lowest and most depraved classes of society. It is become more a place of riot and debauchery, than of public utility.

From what has been stated respecting the provisions annually consumed in London, we are naturally led to inquire into its population; an accurate knowledge of which forms

a foundation for much curious ſpeculation. In the following table we are enabled to give the total number of perſons at four different periods; but it may be neceſſary to premiſe, that the laſt is preſumed to be the moſt correct cenſus ever taken in London.

Population.—London is leſs populous, for its extent, than many other great cities. The ſtreets are wider, and the inhabitants of every claſs, below the higheſt rank, enjoy more room for themſelves and families than is uſual for the ſame claſſes in foreign countries. Hence a given number of people is ſpread over a larger ſpace in London than in foreign cities. From the report on the population of Great Britain, publiſhed on the authority of an act paſſed 43 G. III. London, including the ſuburbs, appears to contain 837,906 ſettled inhabitants; but the great number of ſoldiers, mariners, provincial viſitors, coloniſts, and foreigners, who are conſtantly in London, for purpoſes of pleaſure and buſineſs, and the new inhabitants of 10,000 houſes built within the laſt ſeven years, extends the total population to more than a million. As the increaſe or diminution of the population claims a diſtinct notice, the following table will ſhew its five diviſions, at four different periods.

	In 1700.	1750.	1801.	1811.
1. City of London, within the walls - - - - -	139,300	87,000	78,000	80,000
2. City of London, without the walls, including the Inns of Court -	169,000	156,000	155,000	168,000
3. City and Liberties of Weſtminſter - - - -	130,000	152,000	165,000	180,000
4. Out-pariſhes within the Bills of Mortality - - -	226,900	258,900	379,000	460,000
5. Pariſhes not within the Bills - - - - - -	9,150	22,350	123,000	135,000
Total population of the Metropolis -	674,350	675,250	900,000	1,023,000

Government of London.—In tracing the outline of the preſent government of this metropolis, it will be proper to divide it into three principal parts; *viz.* the city of London, with its dependencies; the city and liberties of Weſtminſter; and the ſuburbs connected with the two, but out of the juriſdiction of both the cities.

The civil government of the city of London is veſted, by charters and grants from the kings of England, in its own corporation or body of citizens. The city is divided into 26 principal diſtricts, called wards; and the corporation conſiſts of, 1, the lord mayor; 2, the aldermen; and 3, the common council. The lord mayor is choſen annually in the following manner: on the 29th of September, the livery, in Guildhall or common aſſembly, chooſe two aldermen, who are preſented to the court of lord mayor and aldermen, by whom one of the aldermen ſo choſen, (generally the ſenior,) is declared lord mayor elect; and on the 9th of November he enters on his office. The aldermen are choſen for life by the free houſholders of the ſeveral wards, one for each ward; except Bridge-ward without, where the election is by the court of aldermen from among thoſe who have paſſed the chair, commonly the ſenior: he is ſtyled father of the city. The common council are choſen annually by the free houſholders in their ſeveral wards, the number for each ward being regulated by ancient cuſtom; the body corporate having a power to extend the number. The common council are the repreſentatives of the commons, and compoſe one of the parts of the city legiſlature, which nearly reſembles that of the kingdom; for as the latter conſiſts of king, lords, and commons, ſo this is compoſed of lord mayor, aldermen, and common councilmen; the principal difference is, that in the three eſtates of the kingdom each enjoys a ſeparate negative, while in the city this right is denied to the lord mayor, and confined to the aldermen and common council. Before the year 1347, there were only two common-councilmen returned for each ward, which, being thought inſufficient to repreſent ſuch a numerous body, it was at that time ſettled that each ward ſhould chooſe a number, not more than twelve, or leſs than ſix, according to its dimenſions; which has ſince been increaſed to the preſent number. The 26 wards are ſubdivided into 236 precincts, for each of which a repreſentative is elected in the ſame manner as the aldermen; with this difference, that as the lord mayor preſides in the wardmote, and is judge of the poll at the election of an alderman, ſo each alderman, in his reſpective ward, preſides at the election of common council men. The civil powers exerciſed by the corporation are very complete: the laws for the internal government of the city are wholly framed by its own legiſlature, called the court of common council, which conſiſts of the lord mayor, aldermen, and repreſentatives of the ſeveral wards, who aſſemble in Guildhall as often as the lord mayor thinks proper to convene them. They annually ſelect ſix aldermen and twelve commoners for letting the city lands, and this committee generally meet at Guildhall on Wedneſdays. They alſo appoint another committee of four aldermen and eight commoners for tranſacting the affairs of Greſham-college, who uſually meet at Mercer's-hall, at the appointment of the lord mayor, who is always one of the number. The court of common council alſo, by virtue of a royal grant, annually chooſe a governor, deputy, and aſſiſtants, for the management of the city lands in Ireland. This court alſo diſpoſe of the offices of town-clerk, common ſerjeant, judges of the ſheriffs'-court, common crier, coroner, bailiff of the borough of Southwark, and city garbler. The election of the recorder is veſted in the court of aldermen only. The lord mayor is the chief magiſtrate of the city: and the aldermen are the principal magiſtrates in their ſeveral wards. The lord mayor, the recorder, the common ſerjeant, and the aldermen, are judges of oyer and terminer (that is, the king's judges to try capital offences and miſdemeanors) for the city of London and county of Middleſex; and the aldermen are perpetual juſtices of the peace for the city. The two ſheriffs, (who are ſtrictly officers of the king, for many important purpoſes of his executive government,) are choſen annually by the livery of London, not only for the city, but for the county of Middleſex, the ſame perſons being ſheriffs for London, and jointly forming one ſheriff for the county. (See Philips's Letter on the Office of Sheriff, 8vo. and SHERIFF.) The adminiſtration, in all its branches, within the juriſdiction of the corporation, in all caſes embracing the city and the borough of Southwark, and in ſome caſes extending beyond, is exerciſed by members of the corporation or its officers. The borough of Southwark was formerly independent of the city of London, and appears to have been governed by

a bailiff till the reign of Edward III., who granted the government of it for ever to the city. A part has been fince incorporated with the city, under the appellation of Bridge Ward Without, and has its officers appointed by the court of common-council. The livery is a numerous, refpectable, and important elective body; in which is vefted the election of the lord mayor, fheriffs, chamberlain, members of parliament, bridge-mafters, ale-conners, and auditors of the chamberlain's accounts. The lord mayor, aldermen, common-council, and livery of London, form together the moft important popular affembly, the commons houfe of parliament excepted, in the kingdom. On occafions of the greateft moment, their decifions have infpired general fortitude; and the whole legiflature, when under evil influence, has been ftruck with awe by the remonftrance of the city, and prudently liftened to a warning fo folemnly pronounced.

The military government of the city of London was confiderably changed by an act of parliament paffed in the year 1794; under which two regiments of militia are raifed in the city, by ballot, amounting together to 2200 men. The officers are appointed by the commiffioners of the king's lieutenancy for the city of London; and one regiment may, in certain cafes, be placed by the king under any of his general officers, and marched to any place not exceeding twelve miles from the capital, or to the neareft encampment; the other, at all fuch times, to remain in the city. Regiments of affociated volunteers are formed in the refpective wards and parifhes, for the internal defence and peace of the metropolis. A confiderable force is alfo maintained by the Bank, India-houfe, Cuftom-houfe, and other public bodies, for their more immediate fecurity. The Artillery company, which is principally compofed of a voluntary enrolment of the younger citizens, affords an additional force of about fix hundred men. (See ARTILLERY.) See alfo Highmore's Hiftory of the Artillery Company, 8vo.

The civil government of the fuburbs is vefted in the juftices of the peace for the county. The county-hall for Middlefex is on Clerkenwell-green, where the quarter-feffions are held; and a great part of the civil government is exercifed. In Bow-ftreet, Covent-garden, is an office of police, under the direction of certain juftices of Middlefex, who dedicate their time chiefly to that office, where are firft examined the moft ferious cafes of mifdemeanor. The other public offices of police, where magiftrates fit daily, are—the Manfion-houfe and Guildhall, within the city. In the fuburbs—Bow-ftreet; Queen-fquare, Weftminfter; Marlborough-ftreet; Hatton-garden; Worfhip-ftreet; Lambeth-ftreet, Whitechapel; High-ftreet, Shadwell; and Union-ftreet, Southwark: at Wapping New-ftairs is an office for enquiry into offences connected with the fhipping and port of London.

The police of London is under the controul of the magiftrates belonging to thefe offices; who are appointed and paid by the government. They are required to attend on duty every day, and their province is to hear and determine petty offences, and fubjects of difpute between individuals. On many occafions they inveftigate felonies, and the higher claffes of crimes, and commit the offenders to the proper prifons. Different acts of parliament have been paffed on this fubject, by which the duty and powers of the magiftrates and fubordinate officers are particularly defined. The police of the city of London is regulated by acts paffed in 10 Geo. II. 11, 14, 33, and 34 Geo. III.: of Weftminfter and its liberties, by acts of 27 Eliz., 16 Cha. I., 29 and 31 Geo. II. 2, 3, 5, 11, and 19 Geo. III.: municipal regulations are alfo eftablifhed in the borough of Southwark, by acts 28 Geo. II. and 6 and 14 Geo. III.

Under the foregoing acts, a nightly watch is appointed for the prevention of robberies, and the apprehenfion of offenders. To the city of London are attached 765 watchmen, and 38 patroles. The whole number of beadles, patroles, and watchmen, who are every night on duty in and around the metropolis, is eftimated at 2044. Watch-houfes are placed at convenient diftances in all parts, where parochial conftables attend in rotation to keep order, receive offenders, and deliver them the next morning to the fitting magiftrate. In the winter feafon, the roads adjacent to London are additionally guarded by horfe-patroles; and on extraordinary occafions, the officers of the police are ordered out, or kept in readinefs, to affift in the prefervation of the public peace. The nightly watch is of peculiar utility in cafe of fire, as in every watch-houfe the names of the turncocks, and the places where engines are kept, are to be found. Befides parochial engines, many public bodies are provided with them, and the principal fire-offices have engines ftationed in various diftricts, with active men and horfes. By means of the fire-plugs, water is immediately fupplied, and the general fecurity is guaranteed by every effort of vigilance and activity.

Acts of Parliament relative to London and its Inhabitants.—The internal economy, government, police, and civil regulations of London, are entitled to particular and commendable notice; becaufe thefe have tended to attract foreigners to fettle here, and induced numerous families, both tradefmen and perfons of fortune, to fix on this city as a defirable place of permanent refidence. It will be found that many legiflative acts have been paffed, and are in force, to fecure the fafety and comfort, and adminifter to the luxuries of the inhabitants of this metropolis. Befides numerous local acts of parliament that apply to particular parifhes and diftricts, the following have been paffed exprefsly for the above purpofes. It is thought advifable to fpecify thefe acts, and point out fome of their items; becaufe many local advantages and conveniences of London are to be referred to thefe legiflative provifions.

By 3 Hen. VII. c. 9, citizens and freemen of London are authorifed to carry their wares to any fair or market in the kingdom, in fpite of any bye-law to the contrary. By 6 Geo. II. c. 22, the lord mayor and citizens were empowered to fill up part of Fleet Ditch, and the inheritance of the ground was vefted in them. By 29 Geo. II. c. 40, the lord mayor and common-council were empowered to purchafe and remove buildings, to improve, widen, and enlarge the paffage over and through London-bridge.

Buildings.—In the year 1764, a very important act of parliament was paffed, refpecting all buildings which are hereafter to be erected within London, Weftminfter, the bills of mortality, and the parifhes of Mary-le-bone, Paddington, Pancras, and Chelfea, whereby it is provided, that they fhall be divided into feven rates, of which the external walls fhall be of a thicknefs proportionate to their rates or fizes; thofe of firft-rate buildings to be at the foundation $2\frac{1}{2}$ bricks, or 1 foot $9\frac{1}{4}$ inches thick, and decreafing upwards in a degree therein fpecified. Another act, of a more ample nature, was paffed in 1774, refpecting the buildings of London and its vicinage. By this it is required, that houfes contiguous to other buildings fhall have party-walls between them, which walls and all chimnies and chimney-fhafts fhall be of brick or ftone, or both together. (See CHIMNEY.) Party-walls fhall be 18 inches above the buildings adjoining, and thofe of firft-rate buildings fhall be at the foundation $3\frac{1}{2}$ bricks, or 2 feet $6\frac{1}{2}$ inches in thicknefs, decreafing upwards in a given proportion. No receffes to be made in party-walls (except for chimnies, fires, girders,

&c.) ſo as to reduce ſuch wall under the thickneſs required. No timber to be in the party-walls (except bonds, templets, and chains, and the ends of girders, beams, &c.) and 8½ inches of ſolid brick-work to be between the ends and ſides of every piece of timber, except oppoſite to other timbers, and then no part of ſuch timber to approach nearer than four inches to the centre of the wall. Surveyors are to give information of irregular buildings, and the lord mayor and juſtices are to order the ſame to be demoliſhed or amended, and 50*s*. penalty is chargeable on the workman. Fire-engines and ladders to be kept in known places in every pariſh; and pariſh officers ſhall place on the mains of water-works, ſtop-blocks, and fire-cocks, and ſhall mark the houſe near. In caſe of fire, the turncock whoſe water comes firſt ſhall be paid 10*s*. Firſt engine 1*l*. 10., the ſecond 1*l*., the third 10*s*. Where officers pay rewards for fires in chimnies only, or beginning there, they are to be reimburſed by the occupier. Servants who through negligence ſet fire to any houſe, ſhall forfeit 100*l*. or be committed to hard labour for 18 months.

Butchers.—It is provided by an act of Hen. VII. c. 3, that butchers ſhall not kill beaſts within the walls of London; but this act is either ſuperſeded or not put in force.

Cattle.—By 14 Geo. III. c. 87, and 21 Geo. III. c. 67. any peace officer may arreſt perſons who drive cattle through the ſtreets of London in an improper or cruel manner. The party, if convicted, ſhall forfeit from 5*s*. to 20*s*. or be committed for one month. Perſons not being drivers of cattle, who ſhall throw ſtones or ſet dogs at them, ſhall be ſubject to the ſame penalties.

Carts.—By 1 Geo. I. ſtat. 2. c. 57, no carman, drayman, waggoner, or other perſon ſhall, within the bills of mortality, ride on a cart, dray, or waggon, not having ſome perſon on foot to guide the ſame, on forfeiture of 10*s*. This penalty is extended to within ten miles of London, by 24 Geo. II. c. 43.

Coals.—By 47 Geo. III. ſeſſ. 2. c. 68, the coal exchange ſhall be a free open market on Monday, Wedneſday, and Friday, from twelve o'clock till two, and coals are only to be ſold in market hours, under a penalty of 100*l*.

Hackney Coaches.—The commiſſioners may licence 800 by act 9 Anne, 200 more by 11 Geo. III., and 100 more by 42 Geo. III.; total 1100. The rates of fares are fixed, and an office is appointed to determine on complaints, which are alſo cognizable by magiſtrates.

Paving, lighting, and cleanſing.—Several acts were paſſed in the reign of Hen. VIII. for paving parts of the metropolis. The eaſtern ſuburbs were paved by act 13 Eliz. Various other acts were paſſed in ſubſequent reigns for paving the ſeveral parts which were added to the metropolis. The *new paving*, according to the preſent mode, commenced in 1763, under an act paſſed in the preceding year. Before this period the ſtreets were extremely inconvenient to paſſengers, the ſtones (moſtly Guernſey pebbles) being round, the kennels in the midſt, and no level footway, as at preſent, for the pedeſtrians. The alterations firſt took place in Weſtminſter, and the improvements progreſſively extended through moſt parts of the metropolis. At this period alſo took place the removal of the enormous ſigns which hung acroſs the ſtreets or over the footways, and, together with their poſts and iron ſcroll works, impeded as well the circulation of the air as the progreſs of the paſſenger.

Lighting.—As early as the year 1416, the inhabitants of London were obliged to hang out lanthorns on winter evenings. Among other improvements in the reign of queen Anne, was the introduction of globular glaſs lamps with oil burners, inſtead of the lanthorns with candles, and common lamps that had previouſly been in uſe. In 1736, an act of parliament was procured to regulate "the better enlightening the ſtreets, &c." within the city. A committee appointed to carry this act into execution, reported that "the number of houſes then inhabited and chargeable (*i. e*. ſuch as were ſubject to poor-rates) was in all 14,014, of which 1287 were under the rent of 10*l*. *per annum*; 4741 of 10*l*. and under 20*l*.; 3045 between 20 and 30*l*.; 1839 between 30 and 40*l*.; and 3092 of 40*l*. and upwards. The number of lamps required was 4200, excluſive of ſuch as were attached to public buildings. They were to be placed at the diſtance of 25 yards from each other in the principal ſtreets, and 35 yards in the ſmaller ſtreets and lanes. This was the commencement of the ſyſtem of defraying the charges of lighting the metropolis by parochial aſſeſſments. Since this time various other acts of parliament have been obtained for different diſtricts in the ſuburbs, and it is conjectured that more than 30,000 lamps are lit every night within the bills of mortality. From Lady-day to Michaelmas, a leſs number is uſed than during the other half of the year. In 1737, an act of parliament was paſſed for regulating and increaſing the city watch, &c. Various acts have been paſt for cleanſing the ſtreets, and preſerving them from obſtructions and nuiſances of every deſcription.

Sewers.—One of the moſt eſſential objects in a large city is good drainage; and in this reſpect London is well provided. Into the deep channel of the Thames, numerous large ſewers communicate, and convey all the ſuperfluous water, and vaſt quantities of filth from the houſes. By acts of the legiſlature, a number of perſons, ſtyled commiſſioners of ſewers, are empowered to make and repair ſewers, and levy a tax on every houſekeeper towards defraying the expences incurred by the ſame. An act of parliament was obtained as early as the reign of Henry VI. on this ſubject; and this has been amended and enlarged by ſubſequent acts, 6th Henry VIII. cap. 10; 23d Henry VIII. cap. 5; and 25th of ſame reign; afterwards in the 3d and 4th of Edward VI.; 1ſt of Mary; 13th of Elizabeth; 3d of James, and 7th of Anne. See SEWERS.

By an act of parliament paſſed in 1737, the number of playhouſes was limited to three, and all dramatic pieces intended for the ſtage, were firſt to be ſubjected to the peruſal and approbation of the lord chamberlain. See PLAYHOUSE.

The Charitable Inſtitutions of London are numerous, of various deſcriptions, and of incalculable advantage. Whilſt they adminiſter comfort, health, education, and protection to the neceſſitous, they reflect much honour on the affluent, and on all the patrons. Theſe conſiſt of hoſpitals, diſpenſaries, alms-houſes, charity ſchools, benefit ſocieties, and other eſtabliſhments. In a former part of this work, under the word HOSPITAL, will be found accounts of ſeveral, to which we ſhall add a few particulars. In the metropolis are 22 hoſpitals for ſick, lame, and for pregnant women; 107 alms-houſes for the maintenance of aged perſons of both ſexes; 18 inſtitutions for the ſupport of the indigent of various other deſcriptions; above 20 diſpenſaries for the gratuitous ſupply of medicine and medical aid to the poor; 45 free-ſchools with perpetual endowments, for educating and maintaining 3500 children; 17 other public ſchools for deſerted and poor children; 237 pariſh ſchools, ſupported by voluntary contribution, in which about 9000 boys and girls are conſtantly clothed and educated: each pariſh has alſo a work-houſe for the maintenance of its own helpleſs poor. Excluſive of this ample liſt, the ſeveral livery companies of

the city of London distribute above 75,000*l.* annually in charities; and there is a multitude of institutions, of a less prominent nature than the foregoing, which make the total of charitable donations immense. The sums annually expended in the metropolis for charitable purposes, independently of the private relief given to individuals, have been estimated at 850,000*l.* The hospitals were chiefly founded by private munificence: some are endowed with perpetual revenues, and others supported by annual or occasional voluntary subscriptions. The alms-houses were built and endowed either by private persons or corporate bodies of tradesmen. Many of the free-schools owe their origin to the same sources. The magnitude of the buildings dedicated to public charities, and the large revenues attached to them, are highly deserving of commendation; and the general administration of these establishments confers a peculiar honour on the capital. The interior regulations of the hospitals well accord with the exterior magnitude: the medical assistance is the best the profession can supply; the attendance is ample; the rooms are generally very clean and wholesome; and the food is proper for the condition of the patients. The alms-houses, and other institutions for the support of the aged and indigent, exhibit not merely an appearance, but a real possession of competence and ease. From some of the free-schools, pupils have been sent to the universities as learned as from any of the most expensive seminaries: and all the scholars receive an education completely adapted to the stations for which they are designed. Among the free-schools may be particularly noted those of Westminster, Blue-coat or Christ's-hospital, St. Paul's, Merchant-taylors', Charter-house, and St. Martin's. For a very ample history and description of all the charitable institutions of London, the reader is referred to a volume published in 1810, entitled, "Pietas Londiniensis; the History, Origin, and present State of the various public Charities in and near London," by A. Highmore, 12mo.

Institutions.—For the accommodation and convenience of the immense population of the metropolis, the following institutions have been formed for education, for promoting good morals, for advancing the useful and fine arts, and for charitable and humane purposes. For education (besides the various schools already mentioned) there are 16 inns of court and chancery for students in the law, &c. (see COURT, *Inns of*,) and five colleges, *viz.* Sion-college, at London-wall, for the improvement of the clergy; Gresham-college, for divinity, astronomy, and other sciences; the college of physicians, Warwick-lane, for professors in medicine; one for the study of civil law, Doctor's Commons; and the Herald's-college. (See COLLEGE.) The number of private schools, for all the various branches of male and female education, is estimated at 3730; including some for children who are deaf and dumb.

For promoting religion and good morals London contains the following societies: 1. For giving effect to the king's proclamation against vice and immorality, established in the year 1787, and for the suppression of vice in 1803: 2. For promoting Christian knowledge, founded in 1699: 3. For the propagation of the gospel in foreign parts, incorporated in 1701: 4. For promoting religious knowledge, by distributing books to the poor, instituted in 1750: 5. For promoting charity schools in Ireland: 6. For religious instruction to the negroes in the West Indies, incorporated in 1795; and African education society, instituted in 1800: 7. For preventing crimes, by prosecuting swindlers and cheats, 1767: 8. For the encouragement of servants, 1792: 9. For the relief of poor pious clergymen, 1788: 10. For giving bibles to soldiers and sailors, 1780: 11. For giving bibles, and otherwise furthering the purposes of Sunday schools, 1785: British and foreign bible society, 1804. To these may be added, Dr. Bray's charity for providing parochial libraries; and queen Anne's bounty for the augmentation of small livings of clergymen.

For the promotion of learning, and advancement of the useful and fine arts, are the following institutions: 1. The Royal society, incorporated for promoting useful knowledge, was instituted 1663: 2. Antiquarian society, Somerset-place, 1751: 3. Society, or trustees of the British Museum, 1753: 4. Royal Academy of Arts, Somerset-place, 1768: 5. Society for encouragement of learning, Crane-court, Fleet-street: 6. Society for encouragement of arts, manufactures, and commerce, in the Adelphi-buildings: 7. Medical society of London, Bolt-court, Fleet-street, 1773: 8. Society for the improvement of naval architecture: 9. Veterinary college, St. Pancras: 10. Royal institution for applying the arts to the common purposes of life, 1799: 11. The London institution, in the city, 1805: 12. The Surrey institution near Blackfriar's-bridge, 1808: 13. The Russel institution, Coram-street, Russel-square, 1808: 14. The Literary fund, established in 179`, &c.

Among the institutions for charitable and humane purposes, the following may be enumerated: 1. The humane society for the recovery of drowned and suffocated persons: 2. Society for the relief of merchants' seamen: 3. Several societies for support of widows in general: and others respectively for the widows and orphans of clergymen, medical men, officers, artists, and musicians; and for decayed musicians, artists, authors, actors, and schoolmasters: 4. Society for relief of persons confined for small debts: 5. Society for ameliorating the condition of the poor. With these benevolent establishments may be classed the friendly or benefit societies, of which there are in the metropolis and its vicinity about 1600, consisting, in general, of from fifty to one hundred members each. The members consist of mechanic and labouring people, who, by small monthly contributions, raise a fund for their support in sickness, and for their funerals, &c. An act of parliament was passed 33 Geo. III. for the special "Encouragement and Relief" of these societies.

Places of Public Amusement.—Considering the vast extent, population, and wealth of London, it certainly contains fewer places of public amusement than any metropolis in Europe. Whether this be the result of accidental causes, or is to be referred to the genius and habits of the people, may, perhaps, be a matter of some doubt. But whatever deficiency exists with respect to number, it yields to no city in the world in the splendour and excellence of those it possesses. Our dramatic authors are not less conspicuous for the brilliancy of their compositions, than our actors are for the judgment and effect which they display in their representation. Mrs. Siddons is, perhaps, the most effective and powerful actress of the present, or of any former age; while her brother, Mr. John Kemble, must be allowed to possess talents of the first-rate description. In the walk of tragedy many other players have evinced very considerable abilities: among the deceased may be named Garrick, Barry, Betterton, Henderson, Booth, Quin, Ryan, and J. Palmer: and those of the present age, most entitled to historic record, are Cooke, Young, and C. Kemble. It may be safely asserted that the comedians of the London theatres have advanced the mimetic art nearly to the height of perfection. The names of the late Messrs. Lewis, King, Parsons, Woodward, Shuter, and Edwin are justly honoured in the annals of the drama; and those of the following actors are entitled to the unqualified commendation of the theatrical critic: Dowton, Munden, Bannister, Fawcett, Emery, Knight, Matthews, Johnson, Lovegrove, Liston, Simmons, and Blanchard. Many

actresses of the present age possess very considerable dramatic powers; particularly mesdames Jordan, Edwin, Duncan, C. Kemble, Gibbs, S. Booth, Davenport, Liston, and Storace. The English stage has many other performers of merit; but their talents are of a more limited nature than the preceding. In the operatic department, or singing, it has long been the fashion to introduce Italian, or foreign singers to the London boards; although many of our native performers unite to fine and powerful voices much science. Mrs. Billington, Mr. Braham, Madame Storace, Mrs. Mountain, Miss Bolton, Mrs. Martyr, Mrs. Bland, Mrs. Dickons, Miss Kelly, Mr. Incledon, Mr. Phillips, and Mr. Bellamy, are justly admired, and have acquired much professional fame. In action or pantomimic representations, many eminent performers are to be found on the London boards. Besides these there are many others very little inferior. Indeed it may be justly observed, that the companies at the principal theatres consist in general of highly respectable performers. The musical votary never had the means of gratifying his taste with a higher relish than at the present period. New compositions of considerable merit daily issue from the press. The list of our vocal performers comprises the names of some of the first singers in Europe. Our instrumental performers are no less celebrated; and our bands in general exhibit specimens of the highest taste and manual skill.

Appropriated chiefly to dramatic performances are the theatres of Drury-lane, Covent-garden, the Lyceum, and the Haymarket. Of these, the two first are upon a style of magnificence and grandeur, scarcely to be surpassed by any theatre in Europe. The last is on a small scale, and opens in summer, when the others close. The King's theatre, or Opera-house, situated in the Haymarket, was originally intended solely for the representation of Italian operas. Of late years, however, dancing has constituted a prominent part of its amusements, to the great injury of the operas, which are generally curtailed of an act to allow time for the ballets. The decorations of this theatre are splendid, and its band is considered as inferior only to that of the Opera-house at Paris. The concert of ancient music, generally called the King's concert, is held in the great room Hanover-square, every week from the beginning of February to the end of May. It owes its origin to a secession from the Academy of Music, another celebrated musical institution. The following is a list of the theatres, and other places of public amusement, now occupied in London, and open to the public; a more particular description of some of these will be given in subsequent parts of this work, under the heads THEATRE and WESTMINSTER.

Covent-garden Theatre is the most eminent for size and dramatic exhibitions. The present building was erected in the year 1809, from designs by Mr. Smirke, jun. architect. It occupies the scite of a former theatre, with connecting houses, which were consumed by fire in September 1808; and it is worthy of remark, that the whole of the present edifice was raised and finished within one year. It is on a large scale, and the whole stage management is vested in Mr. John Kemble, who has certainly made many improvements, and interesting reformations in the internal economy, science, and costumic representation of dramas.

Drury-lane Theatre is now in the progress of building from designs by Mr. B. Wyatt, architect; whose model evinces much skill and judgment. Though not on so large a scale as the theatre of Covent-garden, it combines many conveniences and advantages not to be found in that building; and for seeing and hearing it promises to be very satisfactory to the audience. Mr. Whitbread has taken a very active part in causing this theatre to be rebuilt. A former theatre, built by Mr. Holland, was burnt in 1809.

Theatre Royal Haymarket is a small, inconvenient house, and is allowed to be opened to the public from the 15th of May to the 15th of September.

The Lyceum Theatre, called the *English Opera-house*, is at present occupied by the Drury-lane company of performers, under the management of Mr. Arnold and Mr. Raymond. Operas and comedies are chiefly represented here; and some of these are acted in the best style. Many new dramas have been produced at this house.

The Opera-house, in the Haymarket, is appropriated to Italian operas, spectacles, and dances. The management of this house has occasioned several legal litigations, and is still involved in dispute. Its principle is uncongenial to the English character, and it would be a memorable and laudable act to abolish it. Another similar establishment, arising out of the cabals of the former, and originating with some speculating adventurers, has lately been opened at

The Pantheon in Oxford-road; but after a few nights representation, and after debts of some thousands of pounds had been contracted in fitting up, and adapting the house to the purpose, the theatre is again closed.

Sadlers Wells is a theatre appropriated to pantomimes, burlettas, spectacles, dancing, &c. and commences its season on Easter Monday. The stage performances are invented and written by Mr. C. Dibdin, jun., who has displayed a peculiar and original talent in this species of composition. The musical department is conducted by Mr. Reeve, and the scenery painted by Mr. Andrews. A novelty has been introduced at this theatre, *i. e.* of filling the whole space beneath the stage with water, by which means some splendid and curious aquatic exhibitions have been displayed. It partly resembles the naumachiæ of the Romans.

Astley's Amphitheatre, near Westminster-bridge, is also a summer theatre, where pantomimes, burlettas, and various fetes of horsemanship are displayed. This house also commences its season on Easter Monday, and generally closes in October, when the company remove to another theatre, called

Astley's Olympic Pavilion, in Newcastle-street, where the same species of entertainments are exhibited

The Surrey Theatre, in St. George's-fields, is devoted to a similar class of dramatic representations; but since Mr Elliston has been proprietor and manager of this house, he has adopted a novelty, in abridging and versifying many celebrated dramas, and playing the same with the accompaniment of music.

Another theatre in Wellclose-square, called the *Royalty Theatre*, is occasionally opened; and others are situated in Tottenham-street, in the Strand, and in Bridges-street, Covent-garden.

Vauxhall Gardens are opened twice a week in the summer months, when they are ornamented with an immense number of lamps, and a large concourse of visitors are entertained by vocal and instrumental music. Besides the foregoing, London abounds with many other places of amusement; such as tea-gardens, exhibitions for ingenious inventions, and display of works of fancy, &c.

Among the places of public amusement or exhibitions, may be specified—

The London Museum, in Piccadilly, the property of Mr. W. Bullock, who has devoted many years, much exertion, and a great expence, in collecting and arranging the most comprehensive and interesting assemblage of natural and artificial curiosities that was ever before amassed in England, or perhaps in Europe. His museum was originally commenced at Liverpool; but it has been progressively enlarged and improved. Its preserved specimens in natural history are select, in the highest preservation, and arranged accord-

ing to the Linnæan syſtem. They conſiſt of about 15,000 quadrupeds, birds, reptiles, fiſhes, inſects, corals, &c. One department of the muſeum is peculiarly curious and intereſting. It is called the Pantherion, in which moſt of the known animals, in a preſerved ſtate, and in natural attitudes, are exhibited as ranging in their native, or appropriate haunts; and exact models of exotic plants, rocks, and trees, are diſperſed over the apartment: the whole interior of the ſame is painted in a panoramic manner, repreſentative of oriental ſcenery. For a particular account of this truly intereſting collection, the reader is referred to a printed "Companion to the Muſeum and Pantherion," 12mo. 2*s.* 6*d.* or to a larger work, with etchings, by Howitt, price 14*s.* A new building, in the Egyptian ſtyle, has been erected for this muſeum from deſigns by Mr. Robinſon, architect.

Polito's Muſeum, at Exeter Change in the Strand, contains a choice collection of living beaſts and birds; and to the ſtudents and lovers of natural hiſtory is very intereſting. Here are lions, leopards, tygers, oſtriches, baboons, and monkies of different kinds, kangaroos, beavers, and various other foreign animals and birds. Other muſeums and exhibitions of natural and artificial curioſities are—

Dubourgh's, in Groſvenor-ſtreet, for cork models of ſeveral temples, and ancient buildings in Rome:—*Maillardet's* automatical exhibitions in Spring-gardens, for ſome ſingular works of mechaniſm:—*Week's Muſeum*, Haymarket, is alſo for mechanical works. At *Barker's Panorama*, in Leiceſter-ſquare, are exhibited circular views, on a large ſcale, of ſeveral foreign and Engliſh cities, towns, and other particular ſcenes. Mr Barker has evinced very conſiderable taſte and talents in this branch of art, and to him the public are indebted for the firſt invention of panoramic views. Since he commenced, ſeveral other artiſts have exhibited ſimilar pictures: Mr. Girtin, a view of London; Mr. Porter, ſeveral paintings of battles, and a *New Panorama* is now opened by Reinagle and Barker, in the Strand. See PANORAMA.

The *Fine Arts*, and *Exhibitions of Works of Art*, in London, are entitled to diſtinct and particular notice; for their preſent ſtate is calculated to ſhew the extraordinary progreſs they have made during the laſt century, and to diſplay the highly cultivated condition of the preſent age. London is the focus of the fine arts of England, and fountain-head of excellence. Here all the eminent artiſts of the country either originate, are educated, or terminate their career; becauſe all the great maſters reſide here; the beſt inſtruction is to be obtained; the moſt celebrated productions to be ſeen and ſtudied; and annual exhibitions diſplayed to the public. In the rooms of the Royal Academy at Somerſet-houſe, in thoſe of the Britiſh Inſtitution, Pall-Mall, at Spring-gardens, and in Bond-ſtreet, are annual exhibitions of paintings, drawings, ſculptural and architectural deſigns; and a careful examination of the works here exhibited will furniſh a foreigner with ample means to appreciate the individual and aggregate merits of Engliſh artiſts. Beſides theſe public exhibitions, it will be expedient to viſit the galleries of Mr. Weſt, Mr. Turner, Mr. Wilkie, Mr. Lawrence, and ſome other painters; for in theſe will be found ſeveral of the moſt meritorious works of the age. The beſt productions of our modern ſculptors will be found in the church of St. Paul's and in Weſtminſter Abbey; whilſt the true talents of the architects can only be appreciated by a perſonal examination of the buildings they have erected. The public inſtitutions devoted to the fine arts are the following:

At the *Royal Academy*, in Somerſet-houſe, is an annual exhibition, for the period of about ſix weeks, of paintings, drawings, ſketches, models, and proof-prints. This academy was eſtabliſhed by charter in the year 1768, and ſir Joſhua Reynolds appointed its firſt preſident. To this great artiſt's talents as a painter, conduct as a man, and writings on art, the Royal Academy is eſſentially indebted for its proſperity and reputation. His faſcinating productions, engaging manners, and luminous diſcourſes on painting, attracted the attention and patronage of many perſons of diſtinction, and at the ſame time rouſed the emulation and active zeal of the junior artiſts. Since ſir Joſhua's time, Mr. Weſt has occupied the preſidential chair, with little interruption, and has honoured the academic exhibitions with a continued ſucceſſion of new pictures in the higheſt branch of art. A ſeries of lectures has been annually given at the academy by different profeſſors; all calculated to advance art, and inculcate proper principles of taſte and criticiſm. Some of the preſent lecturers are deſervedly famed for profeſſional ſcience, as well as for general knowledge. In the years 1811 and 1812, the following profeſſors delivered lectures on their reſpective provinces of art: Henry Fuſeli, on painting; John Soane, on architecture; Anthony Carliſle, on anatomy (it is neceſſary to ſtate that this gentleman is not a member of the academy); J. M. W. Turner, on perſpective; and John Flaxman, on ſculpture. The Royal Academy conſiſts of forty members, called Royal Academicians, twenty aſſociates, and ſix aſſociate engravers. Further particulars of this inſtitution will be given under ROYAL *Academy*.

The *Britiſh Inſtitution*, in Pall-Mall, was eſtabliſhed by the liberal contributions of ſeveral noblemen and gentlemen in the year 1805, for the expreſs encouragement of Britiſh artiſts: and it muſt afford much gratification to the founders to contemplate its great utility and ſucceſsful effects. This inſtitution is devoted to the exhibition and ſale of pictures; and to the uſe of young ſtudents for copying from and ſtudying old paintings. Another plan has been recently adopted, which is calculated to enhance its utility and reputation. This is the purchaſe of pre-eminent pictures, which are to be preſerved as the property of the inſtitution, and from which engravings are to be made on a large ſcale. The firſt of this ſeries is a large painting by Mr. Weſt, of "Chriſt healing the Sick in the Temple!" and Charles Heath is engraving a plate from it.

The Society of Painters in Water-Colours was eſtabliſhed in November 1804, ſince which time they have annually exhibited a large and intereſting collection of drawings. This branch of art may be ſaid to have attained nearly the higheſt excellence; and many of its profeſſors have manifeſted diſtinguiſhed talents. In colouring, effect, and appropriate character, ſeveral young artiſts of the preſent age have ſurpaſſed any of the old maſters in this branch of art. Another ſociety of artiſts have made an annual exhibition of drawings in Bond-ſtreet. The collections of pictures in private houſes in London are numerous, and many of them very valuable. The moſt celebrated of theſe are the marquis of Stafford's, at Cleveland Houſe; (for an account of theſe pictures, ſee Britton's "Catalogue Raiſonné," and Treſham's "Gallery of Pictures;") the collection at Buckingham-houſe; the earl of Groſvenor's, in Groſvenor-ſtreet; Mr. Thomas Hope's, in Ducheſs-ſtreet; Mr. H. W. Hope's, in Cavendiſh-ſquare; Mr. Anderdon's, Spring Gardens; Mr. Weſt's, in Newman-ſtreet; earl of Suffolk's, in Harley-ſtreet; the duke of Devonſhire's, in Devonſhire-houſe; Mr. Angerſtein's, Pall-Mall; ſir Abraham Hume; ſir George Yonge, in Stratford-place; lord Northwick's, in Hanover-ſquare; Mr. Weddel's, in Upper Brooke-ſtreet; lord Aſhburnham's, in Dover-ſtreet; baroneſs Lucas, in St. James's-ſquare; ſir George Beaumont, in Groſvenor-ſquare; Mr. William Smith, in Park-ſtreet; Mr. Knight, of Portland-place; Mr. Jeremiah Harman, of Finſbury-ſquare; Mr. R. P.

Knight, of Soho-ſquare; lord Radſtock, in Portland-place. Beſides theſe, there are many other collections of fine pictures in various parts of the metropolis. For much uſeful information reſpecting the fine arts in London, &c. ſee Hoare's "Inquiry into the preſent State of the Arts of Deſign in England," 8vo. 1806; alſo two other volumes in 4to. edited by the ſame intelligent and liberal writer, entitled "The Artiſt, in a Series of Eſſays;" alſo, "The fine Arts of the Engliſh School," 4to. 1812; Britton's Preface to an Account of the Corſham-Houſe Collection; and Edwards's Anecdotes of Painters in England, 4to. 1808.

Courts.—For an account of the various courts of London, the reader is referred to a former volume, under the head COURT *of Common Pleas, of Chancery, of Exchequer, of Huſtings, of King's Bench, of Marſhalſea, Mayor's, of Parliament,* (ſee PARLIAMENT,) *of the Houſe of Peers, of Star Chamber;* alſo, INNS *of Court.*

Literature and literary Publications.—To give a view of the literature of this metropolis, and to point out its preſent ſtate, compared with that of any former period, would be to develope one of the moſt intereſting traits, not only of London, but of the preſent age. The number and variety of works which annually iſſue from the metropolitan preſs are truly aſtoniſhing; while in point of ability and uſefulneſs they were probably never exceeded. There is not indeed a department, either in ſcience or general literature, which has not made conſiderable progreſs within theſe few years. The publiſhing and bookſelling buſineſſes are at preſent conducted upon very large ſcales; and, in ſpite of a long and devaſtating war, a ſucceſſion of new and intereſting volumes is continually iſſuing from the preſs. It is conjectured that nearly 800 new books and pamphlets have been annually publiſhed in London, during the laſt ten years: the groſs annual returns ariſing from the printing and ſelling of which cannot be much ſhort of one million ſterling. It is alſo eſtimated that 2000 perſons at leaſt are directly and collaterally employed in the various branches of the book buſineſs. The character and extent of periodical literature form a prominent feature of the preſent age: for the number of reviews, magazines, newſpapers, and other periodical journals, far exceed thoſe of any former period. Hence much political and general knowledge has been diſſeminated through the country; a ſpirit of inquiry and inveſtigation has been excited; and a literary turn has been given to the higher and middle claſſes of ſociety. Even the lower claſſes of mechanics and ſervants are now much accuſtomed to reading: one of the conſequences ariſing from which is that we frequently hear of men of genius and talents ſtarting up from humble ſtations, and diſplaying to the aſtoniſhed world much originality of thinking. Many inſtances of this might be adduced; but it will be ſufficient to name two or three, to prove the aſſertion: Burns, Dermody, and Bloomfield, the poets; and Drewe, the metaphyſician of Cornwall. Nothing can more plainly ſhew the reading character of the preſent times, than a knowledge of the number of newſpapers printed and circulated; and which number is thus ſtated in "The Picture of London for 1812:" "Of the morning papers, there are ſold about 17,000 of theſe publications; of the daily evening papers, about 12,000; and of thoſe publiſhed every other day, about 10,000. There are alſo about 26,000 ſold of the various Sunday papers; and about 20,000 of the other weekly papers: in all, the enormous number of 232,000 copies *per* week; yielding to their proprietors from the ſale 5800*l.*, and from advertiſements 2000*l.* more; of which the revenue to government is full 4000*l.* and the net proceeds to the proprietors about 1000*l.*; the remaining 2800*l.* affords employment and ſubſiſtence to about 50 writers and reporters, 300 printers, 100 vendors, and 100 clerks and aſſiſtants; beſides paper-makers, ſtationers, type-founders, &c. full 200 more. If to theſe be added the weekly calculation of 250,000 copies of provincial papers, yielding 10,000*l.* *per* week, and ſupporting the induſtry of 1500 perſons;—what a wonderful idea is afforded of the agency and influence of the preſs in this empire; and how eaſily is it accounted for, that we are the moſt free and moſt intelligent people on the face of the earth." Under the words MAGAZINE, NEWSPAPER, and REVIEW, we ſhall have opportunities of detailing many facts and peculiarities reſpecting theſe different publications. See alſo JOURNAL, *Literary.* London abounds with bookſellers' ſhops and circulating libraries. It is aſſerted that the firſt circulating library eſtabliſhed in this town was by a Mr. Baths, about the year 1740; but Alan Ramſay had founded one at Edinburgh as early as the year 1725. In London there are publiſhed ſeventeen newſpapers daily, and eighteen or nineteen every Sunday, beſides eighteen once or twice a week. The number of monthly magazines and reviews amounts to fifty; in addition to which, there are ſeveral works publiſhed quarterly, or at irregular periods.

Societies for the Encouragement of the Arts, Sciences, &c.—London poſſeſſes a variety of inſtitutions formed with a view to the advancement of the different branches of art and ſcience; among theſe the Royal Society undoubtedly takes the lead, being compoſed of the moſt diſtinguiſhed literary and ſcientific characters of the preſent age. It was firſt inſtituted at the cloſe of Cromwell's rebellion, at which time its meetings were held at Oxford. In 1659 they were adjourned to Greſham college, London; but of late years have been held at an apartment in Somerſet houſe. This ſociety was incorporated in 1663, when the celebrated ſir Iſaac Newton was preſident, and has, through the medium of its Tranſactions, and by its patronage, probably contributed, more than any ſimilar body in the world, to promote uſeful and practical knowledge. (See ROYAL *Society.*) The ſociety of Antiquaries, which holds its meetings in the ſame place with the Royal Society, was incorporated by Geo. II. in the year 1751. The object of this ſociety is to encourage reſearch in the elucidation, not only of our national antiquities, but of the antiquities of other countries. It has publiſhed ſixteen volumes, called the Archæologia, containing many curious and intereſting eſſays and prints, alſo a large work illuſtrative of our eccleſiaſtical architecture. (See SOCIETY *of Antiquaries,* and ANTIQUARY.) The ſociety for the encouragement of arts, manufactures, and commerce, inſtituted in 1753, and holding its meetings in the Adelphi, propoſes the attainment of its object by giving premiums for all inventions and diſcoveries which may prove, and are calculated to be, beneficial to the arts, commerce, or manufactures of the kingdom, the Britiſh colonies, or the Eaſt India ſettlements. A volume of the Society's tranſactions is publiſhed occaſionally. The walls of the great room, in which its meetings take place, are adorned with a variety of paintings from the pencil of Mr. Barry, the ſtyle and execution of which have inſured him deſerved immortality, and are really an honour to the country. The Linnæan ſociety was founded in 1788, and incorporated in 1802. (See *Linnean* SOCIETY.) The Royal Inſtitution, ſituated in Albemarle ſtreet, owes its foundation chiefly to the ſchemes and exertions of count Rumford. Its charter of incorporation is dated in 1800. The original object of this inſtitution was to facilitate the introduction of uſeful diſcoveries and improvements in practical mechanics, and to point out, by philoſophical lectures and experiments, the application of ſcience to the common purpoſes of life. The inveſtigations and important diſcoveries of Dr. Davy, the

lecturer on chemistry, have conferred no small degree of celebrity on this establishment, while they will not improbably be the means of effecting a complete change in our views of chemical analysis. (See ROYAL *Institution.*) The London Institution, as well as the Surrey Institution, embrace similar objects to the one preceding. The former was founded in 1805, and the latter in 1808. Both have extensive libraries and reading rooms, furnished with many of the foreign and domestic journals and other periodical works, together with the best pamphlets and new publications. The views of the Russel Institution are the formation of an extensive library, consisting of the most valuable books in ancient and modern literature, to be circulated among the proprietors, the delivery of lectures on literary and scientific subjects, and the establishment of a reading room. In Gresham college, founded by sir Thomas Gresham, lectures are delivered gratis twice a day during the terms, on divinity, law, physic, astronomy, geometry, music, and rhetoric. As it happens in all institutions on a similar plan, the lecturers, having no stimulus to exertion, consider their duty as a mere matter of routine, and are consequently ill attended. Some idea is entertained of transferring them and the funds to the London Institution, where it is hoped they may be more efficient, and answer better the design of the benevolent founder. The British Mineralogical Society was established in 1799, for the express purpose of examining gratuitously the composition of all specimens of minerals and soils, sent for that purpose by the owners of mines, agriculturalists, or others interested in the enquiry. The science of entomology will probably be much forwarded by the institution of the Entomological Society, which took place in 1806, and which chiefly directs its attention to the investigation of the properties of such insects as are natives of the united kingdoms. The London Architectural Society has published a volume of Essays, 8vo. 1808: also an Essay on the Doric order. The Horticultural society was founded in 1804. A Geological Society is established by some scientific gentlemen in Lincoln's-inn-Fields; they have recently published an interesting volume of their transactions. Before we quit these institutions it may be proper to remark, that the number and variety of lectures that have been read in them must have proved beneficial to science; by exciting inquiry, and investigating facts by experiment. Till these institutions were established, there were but few public lectures given in London; such, however, have been the influence and effect of them, that during the winter of 1811-12, it may be asserted that no less than fourteen courses have been given at the Royal, Russel, and Surrey Institutions. We subjoin the names of the principal professors: Dr. Davy, Dr. Roget, Dr. Crotch, J. M. Good, esq., Geo. John Singer, esq., Dr. Shaw, F. Accum, esq., Sam. Westley, esq., Mr. Hardie, Robert Bakewell, esq., Dr. Brande, James Quin, esq., John Pond, esq., and Wm. Haslitt, esq

The British Museum, situated in Great Russel-street, is a grand national depository of antiquities, MSS. and books, with various natural and artificial curiosities. It was established by act of parliament in 1753, in consequence of sir Hans Sloane having left, by will, his museum to the nation, on condition that parliament paid 20 000*l*. to his executors, and purchased a house sufficiently commodious for its reception. Since that period many valuable collections of manuscripts, books, &c. have, at different times, been added to the Sloanean, besides innumerable presents from our own monarchs, foreign princes, the boards of Admiralty and Longitude, the East India Company, the various literary societies of London, Edinburgh, Oxford, Cambridge, and Leyden, the Royal and Imperial academies of Brussels, Lisbon, &c. and a long list of private individuals, too numerous to be particularized. The vast variety of articles which this museum contains, its extent and value, entitle it to be considered equal to any in the world. Under the word MUSEUM will be given further particulars of this national repository; in the mean time the reader is referred to a "Synopsis of the Contents of the British Museum," 8vo. 1808; and to a quarto work of "Engravings from the Gallery of Antiquities in the British Museum," by Mr. Taylor, Combe, and Mr. Alexander. This very handsome and interesting work is now in the progress of publication, and is very creditable to the trustees who have commenced it, and to the draftsman and author by whom it is chiefly executed.

Public Vices and Prisons.—The general tendency of the preceding statements only shew the best and most interesting features of the metropolis. It is our duty also to depict its vices; and to shew the numerous places that are set apart for the punishment of crimes. In Colquhoun's work on "the police of the metropolis," is such a deplorable display of profligacy and criminality, that an inexperienced reader, who knew London only through the medium of this publication, would conclude that its inhabitants were mostly composed of vagabonds, sharpers, pickpockets, and prostitutes. It should be remembered, however, that the work is chiefly devoted to this subject; and that, amidst so vast a population, and where there are so many opportunities for rogues to practise their depredations, and screen themselves from detection, it is not surprising that so many are collected together, and that out of a great number so few are brought to condign punishment. To this great hive of human society, the most vicious, and also the most learned resort, as the best place for action and exertion. The worthy magistrate already named, has enumerated and described eighteen different classes of cheats and swindlers who infest the metropolis, and prey upon the honest and unwary: besides persons who live by gambling, coining, housebreaking, robbery, and those who plunder on the river. He deduces the origin of most of the crimes from alehouses, bad education of apprentices, servants out of place, Jews, receivers of stolen goods, pawnbrokers, low gaming-houses, smuggling, associations in prisons, and prevalence of prostitution. No less than 50,000 prostitutes are supposed to live in the metropolis. An amazing number, and a distressing circumstance to contemplate: for it is presumed that eight-tenths of these die prematurely of disease and in wretchedness, having previously corrupted and contaminated twice their own number of young girls and young men. The following is a list of the public prisons.

1. Newgate, being the city and county goal for debtors, felons, libellers, and other offenders against government. See NEWGATE.

2. Giltspur-street Compter was erected in 1791, for debtors, felons, and persons committed for misdemeanors. It is situated near Newgate, and is a large, commodious building.

3. Ludgate, adjoining to the last mentioned, is appropriated only to debtors who are freemen of the city of London, clergymen, proctors, or attornies.

4. The Poultry Compter is chiefly for debtors. It is situated near the Mansion-house, and has one ward set apart for Jews: the only prison in England that has such a provision.

5. The Fleet Prison is for debtors, and for such persons as are committed for contempt of the courts of chancery.

6. The Savoy Prison, in the Strand, is exclusively devoted to deserters and military delinquents.

7. The New Prifon, Clerkenwell, is the goal for the county of Middlefex, for felons, and perfons fined.

8. The Prifon for the Liberty of the Tower of London, is at Bethnal-green, and is ufed only for foldiers belonging to the Tower.

9. Whitechapel Prifon for debtors in the *5l.* court.

The houfes of correction are

10. The City Bridewell, Bridge-ftreet, Blackfriars.

11. Tothill-fields Bridewell.

12. Cold Bath Fields Penitentiary Houfe.

13. New Bridewell, in the borough of Southwark.

14. County goal for Surrey, in the borough of Southwark, for felons and debtors.

15. New goal, Southwark, or Borough Compter, for felons and debtors.

16. Clink goal, for the diftrict of that name, in Southwark.

17. The Marfhalfea goal, Southwark, for pirates, and for perfons arrefted for fmall debts in the Marfhalfea court.

18. King's-bench prifon, St. George's Fields, for debtors, and for perfons committed for contempt of the court of King's-bench, of which this is the peculiar prifon.

Public Buildings.—It will furprife a foreign architect to look through the wealthy city of London, and perceive fo few public edifices that difplay architectural beauty, or grandeur. Various circumftances have confpired to occafion this; and not want of abilities in our artifts: for many names can be mentioned, both of deceafed and living architects, whofe defigns would honour and ornament any city. Thofe whofe works are moft confpicuous in London, are Inigo Jones, fir Chriftopher Wren, Gibbs, Hawkfmoor, Dance, Soane, Samuel Wyatt, Jupp, fir Robert Taylor, Smirke, Milne, Holland, and Adams. The public edifices of London, are bridges, (for an account of which fee BRIDGES,) churches, public offices, hofpitals, and private manfions. Squares and regular ftreets conftitute a diftinguifhing feature of town architecture. Some of the public buildings are fpacious, commodious, judicioufly adapted to their refpective purpofes, and difplay beautiful, fine, and even grand parts. The Englifh architect is juftly noted for the fkill and judgment he often evinces in defigning and adapting the interior of his buildings: and this is certainly the moft effential part of the profeffion. The principal public edifices within the precincts of the city, and in the eaftern part of the town, are the Tower; the New Mint; the Trinity Houfe; the Bank; the Manfion Houfe; the Royal Exchange; the Eaft India Houfe; the Auction Mart; the Commercial Mart; the Cuftom Houfe; the Excife Office; Guildhall; the bridges of London and Blackfriars; the Poft-office; Newgate; Giltfpur-ftreet Compter; St. Luke's Hofpital; the churches of St. Paul, Bow, St. Stephen's Walbrook, St. Bride's Fleet-ftreet.

Tower of London.—This celebrated building ftands on the north bank of the river Thames, at the eaftern extremity, and juft without the limits of the city. If credit is to be given to the ftatement of Fitz-Stephen, it owes its original foundation to Julius Cæfar, but this affertion is fupported by no evidence. The firft authentic notice of it is, that William the Conqueror erected a fortrefs here immediately upon his obtaining poffeffion of London in the year 1066, with the view of intimidating the citizens from any oppofition to his ufurpation. This monarch feems, about twelve years afterwards, either to have much enlarged the previous edifice, or to have built another on its fcite or near it. This building forms, what is now called, the White Tower, from its having been repaired and white-wafhed by Henry III. in the year 1240. It is a large fquare ftructure, fituated near the centre of the prefent fortrefs, and furmounted by four watch towers, one of which is ufed as an obfervatory. It confifts of three lofty ftories, in the firft of which are two grand rooms, one of which is a fmall armory for the naval fervice. The other buildings and fortifications have been erected at different periods. The principal of the former are, the church dedicated to St. Peter *ad vincula*; the ordnance office; the mint; the record office; the jewel office; the horfe armory; the grand ftore-houfe; the new or fmall armory houfes belonging to the officers of the Tower, and barracks for the garrifon. The whole comprifes, within the walls, an extent of twelve acres and five roods. The exterior circumference of the ditch, which entirely furrounds it, meafures 3156 feet. This ditch, on the fide of Tower-hill, is broad and deep, but becomes much narrower on that neareft the river, from which it is divided by a handfome wharf, having a platform upon it, mounted with fixty-one pieces of cannon. Befides thefe, there are a number of great guns, arranged as fmall batteries, on different parts of the walls. The chief entrance is by a ftone bridge thrown over the ditch on the weft-fide of the Tower. At the outer extremity of this bridge are two gates, and within the ditch another, all which are fhut every night, and opened in the morning with particular formality. The wharf is connected with the Tower by a drawbridge, near which is a cut leading from the ditch to the river, fecured by a gate called Traitor's Gate, from the circumftance of ftate prifoners having been formerly conveyed by this paffage to Weftminfter for trial.

This fortrefs was a palace, inhabited by various fovereigns of England till the reign of queen Elizabeth. Since that period it has been chiefly ufed as a ftate prifon, and as a place of fecurity for arms and property belonging to the crown. In one of the rooms of the White tower, called Cæfar's chapel, a variety of ancient records of the court of chancery are depofited. All the models of new invented engines of deftruction, which have been prefented to government, are preferved in another room adjoining. The old mint, and the houfes belonging to the officers employed in the coinage, occupied nearly a third of the whole fortrefs. A yard, to the right of the weftern entrance, contains the royal menagerie. In the Spanifh Armory are kept the trophies of the celebrated victory over the Spanifh armada; the axe with which the unfortunate Anne Bullen was beheaded; and a reprefentation of queen Elizabeth, dreffed in the armour fhe wore when fhe addreffed her army at Tilbury, in the year 1588. The Small Armory, one of the fineft rooms of its kind in Europe, contains complete ftands of arms for upwards of 100,000 men, arranged in a moft elegant manner, befides other curiofities. Under this armory is another very noble room belonging to the royal train of artillery, where many beautiful and uncommon pieces of cannon may be feen. The Horfe Armory is filled with curiofities of different kinds. Among thefe are the figures of the kings of England on horfeback, chiefly dreffed in the ancient armour. In the Jewel Office are preferved the imperial regalia, and all the crown jewels worn by princes and princeffes at coronations. Independently of feveral, which are ineftimable, the value of the precious ftones and plate in this office confiderably exceeds two millions fterling. Thefe, as well as the government of the whole Tower, are entrufted to the care of an officer, called the conftable of the Tower, who has under him a lieutenant, deputy-lieutenant, tower-major, gentleman porter, and a number of inferior officers. The garrifon is compofed of a detachment from the guards. The rifing ground adjacent to the

Tower is called Tower-hill. The right of the city to this ſpot was long diſputed by the crown, but in the reign of Edward III., ſome of the king's officers having erected a gallows here, the citizens remonſtrated, whereupon that monarch iſſued a proclamation, which he diſavowed in the act, and virtually acknowledged the city's juriſdiction, by delivering over the perſons about to be executed to the ſheriffs; and deſiring that they ſhould preſide at their execution. On the ſcite of the old victualling office, to the eaſt of the Tower, an extenſive building has been lately erected from deſigns by Mr. Smirke, jun. for the Mint. It is compoſed of a long front of ſtone, conſiſting of a ground-floor, with two ſtories above; the whole ſurmounted by a handſome baluſtrade. The wings are ornamented with pilaſters, and in the centre are ſeveral demi-columns, over which is a pediment, decorated with the arms of England. The porch is covered with a gallery, baluſtrades, &c. all of the Doric order. Adjoining are houſes for the principal officers.

Manſion-houſe.—This building, the reſidence of the lord mayor of London, is ſituated to the weſt of Lombard-ſtreet and Cornhill. It is of an oblong form, and conſtructed of Portland ſtone. From its maſſive ſtyle and vaſt extent, it is calculated to make a magnificent appearance, but the effect is deſtroyed by its confined ſituation. A wide and lofty portico, compoſed of ſix fluted pillars of the Corinthian order, with two pilaſters at each ſide of their pediment, of the ſame order, form the chief ornament of the front. Under this portico is a low baſement ſtory, in the centre of which is the gate-way leading to the kitchen and offices. A flight of ſteps aſcends to the principal entrance door-way beneath the portico. Theſe ſtairs are incloſed by a ſtone baluſtrade, continued along the whole length of the front. The pediment of the portico is adorned with a piece of ſculpture emblematical of the wealth and grandeur of the city. In the centre is a female figure repreſenting the city, having a wand in her right hand, and her left reſting on the city arms. On her head is a mural crown, and under her left foot a figure of Envy. Near her on the right is a cupid, with the cap of liberty affixed to a ſhort ſtaff, leaning on his ſhoulder, and beyond him reclines a ſea god, to repreſent the Thames, having at his ſide an anchor faſtened to a cable. To the left of London is Plenty, with a cornucopia, and behind her two naked boys, with bales of goods to denote Commerce. The weſt ſide of this edifice preſents a range of very noble windows, placed between coupled Corinthian pilaſters. Its interior exhibits a ſufficient degree of ſplendour, but is far from being comfortable, as many of the rooms are dark. Some of the apartments are very large, and fitted up in a ſumptuous ſtyle; particularly the Egyptian hall, the ball-room, &c.

Commercial Hall.—It has long been a complaint in the city that ſome reſpectable place of general accommodation was wanted for the diſpoſal of imported merchandize, but principally for that of colonial produce. Several attempts have been made to remedy this defect, but without ſucceſs. About a year ago, Meſſrs Smith, Marten, and St. Barbe called a meeting of merchants and brokers, in order to eſtabliſh an inſtitution for this purpoſe. A large ſubſcription was raiſed almoſt inſtantly, and as ſoon as a plot of ground, ſufficiently large, and in a ſuitable ſituation, could be procured, a number of plans were ſubmitted by different architects, from an examination and compariſon of which, a new deſign was formed and carried into execution under the direction of J. Woods, jun. whom the committee choſe for their architect. The original intention of the eſtabliſhment was principally for the accommodation of public ſales, but it has been extended to provide equal conveniences for ſale by private contract; and thus to form a complete market for ſugar, cotton, coffee, tobacco, indigo, and other imported goods.

The building is compoſed of two principal parts. The front conſiſts of an entirely new edifice, 64½ feet long, and 39 feet broad, with a ſtone front, ornamented with ſix columns of the Ionic order, adopted, with little variation, from the temple of Minerva Polias, at Priene. Theſe columns are ſupported on pedeſtals, which reſt on the cornice of an inferior order, compoſed not of columns but of piers, whoſe ſquareneſs and ſolidity form a contraſt with the lighter and more varied proportions of the columns above. This order of piers forms the ground ſtory of the building. The ſpaces between the pedeſtals are filled up with baluſters, and above the windows, which are large and ſuited to the ſcale of the building, are five bas-reliefs, executed in artificial ſtone by Bubb: the middle compartment repreſenting the city of London, the four others, Navigation, Commerce, Agriculture, and the Arts. The whole of the ground-floor of this edifice is occupied by a magnificent coffee-room, at one end of which, between two columns, appear the ſtairs leading to two public ſale-rooms, one of which is about 35 feet by 30, and again on the upper floor to three more ſale-rooms, each about 25 by 20 feet.

The ſecond building formerly conſiſted of three houſes, which are now thrown into one: the lower floors are divided into a number of counting-houſes, the upper into five ſhow-rooms, the largeſt of which, ſixty feet long, is appropriated for the exhibition of goods intended for ſale.

Particular attention has been paid to the lights in theſe rooms, and by a ſucceſſion of ſky-lights ſloping to the north the perfect light of day is admitted, and the ſun effectually excluded. The ſpace between theſe buildings, and that behind the latter on the ground-floor, is occupied by a number of rooms lighted in the ſame way, all of which are intended for the ſale of ſugars.

The object of this building is the attainment of public convenience; by bringing into one point what before had been ſcattered among ſeveral coffee-houſes, and the rooms of individuals.

Eaſt India Houſe.—This edifice is ſituated on the ſouth ſide of Leadenhall-ſtreet, and compriſes the principal offices of the Eaſt India Company. It was originally founded in the year 1726, but has recently been ſo much altered and enlarged, under the ſuperintendance of Mr. Jupp, architect to the company, as to appear like an entire new building. The front, compoſed of ſtone, is very extenſive, and diſplays a general air of grandeur and ſimplicity. In the centre riſes a noble portico, ſupported by ſix Ionic fluted columns. The frieze is ſculptured with a variety of antique ornaments, and the pediment exhibits ſeveral figures emblematical of the commerce of the company, protected by his majeſty, who is repreſented in the act of extending a ſhield over them. On the apex of the pediment is placed a ſtatue of Britannia, to the eaſt of which is a figure of Aſia, and on the weſt another of Europe. The interior can boaſt of ſeveral very noble apartments, particularly the ſale-room, which may be juſtly reckoned among the curioſities of the metropolis. In this houſe the courts of the Eaſt India Company are held, and all its official and general buſineſs tranſacted. Several large and commodious warehouſes are diſtributed in different parts of the towns, where teas and other imported goods are depoſited. See COMPANY, *Eaſt India.*

The London Monument.—This noble pillar, perhaps the fineſt in the world, ſtands on the eaſt ſide of Fiſh-ſtreet-hill, about two hundred yards from the north end of London bridge. It was erected by the celebrated ſir Chriſtopher Wren, to commemorate the dreadful fire of 1666, which deſtroyed a great part of the city, and commenced near this ſpot. This monument is a fluted column of the Doric order, with a baſe and capital, ſurmounted by a ball. Its diameter at the baſe is fifteen feet. The maſſy pedeſtal meaſures 40 feet, the column 120, the cone above it, with its urn, 42, ſo that the entire height of the pillar is 202 feet. The interior contains a flight of 345 ſteps, aſcending to a balcony, from which the viſitor has a very extenſive proſpect of the metropolis and the adjacent country. The obſcure ſituation of this beautiful and majeſtic pillar is much to be lamented, for were it placed in a conſpicuous poſition, it would form a great and ſtriking ornament to the metropolis.

The Poſt-Office is ſituated in an area on the ſouth ſide of Lombard-ſtreet. As a building, it is not only unworthy of notice, but when the importance and magnitude of its concerns are conſidered, is really a diſgrace to the country and the metropolis. Such an important eſtabliſhment ſhould be well and properly accommodated. As a national inſtitution, however, it deſerves particular attention, being perhaps the moſt perfect ſyſtem of internal economy, of its kind, in the world: it keeps up a conſtant communication, directly or indirectly, with every town in the united kingdom, as well as with every foreign port in the moſt remote degree connected with the Britiſh empire. It poſſeſſes likewiſe the double advantage of being incalculably uſeful to individuals, and affording a large revenue to the government. Indeed, of all the means of finance any miniſter ever employed, it is beyond compariſon the beſt; while at the ſame time it may juſtly be regarded as the ſoul of commerce. The preſent poſt-office was built in 1760, but ſince that time great additions have been made to the building. At the commencement of the poſt-office ſyſtem, the whole was veſted in private perſons, and was irregular, defective, and inſecure. A few years back a very important plan was ſuggeſted by Mr. Palmer, of conveying letters to all parts of the kingdom by means of mail coaches; whereby a ſpeedy communication, and ſecurity from robbery were effected. See MAIL COACHES, and POST-OFFICE.

The Trinity Houſe.—On the north ſide of Tower-hill is a large, handſome, regular building, which was erected from deſigns by Samuel Wyatt, architect. The chief buſineſs of the Trinity-houſe corporation, which was founded in 1512, is conducted here, though the old eſtabliſhed houſe is at Deptford. The corporation conſiſts of one maſter, four wardens, eight aſſiſtants, and twenty-eight elder brethren, who are ſtyled "the guild, or fraternity of the moſt glorious and undivided Trinity, and of St. Clement, in the pariſh of Deptford-Strond, in the county of Kent." The object of this corporation is to ſuperintend and guard the intereſts of the Britiſh ſhipping, both military and commercial. Their powers are extenſive; and their objects important. They have to examine the children who are inſtructed in mathematics in Chriſt's hoſpital; examine the maſters of the king's ſhips; appoint pilots for the Thames; erect light-houſes and ſea-marks in the Britiſh ſeas; grant licences to poor ſeamen who are not free of the city, to ply for fares on the Thames; ſuperintend the deepening and cleanſing of the river, &c. The Trinity-houſe contains ſome handſome apartments, particularly the hall, the ſtair-caſe, and the court-room; in one of which is a fine model of the ſhip called the Royal William; alſo portraits of twenty-four of the elder brethren, and of other eminent perſons.

The Lunatic Hoſpital, called St. Luke's, in Old-ſtreet, a large pile of building, was erected from deſigns by George Dance, who alſo built the priſons of Newgate and the city Compter. In all theſe he manifeſted much ſkill and judgment; but there is a great want of both in the new front.

The Guildhall of the city is a piece of architectural abſurdity.—It is appropriated to the chief public offices of the corporation of London: the principal of theſe is the great hall, (153 feet long, by 48 broad and 55 high,) in which the large city feaſts are held, where public meetings are aſſembled, and the lord-mayor and members of parliament elected. Here are ſeveral portraits of ſovereigns, judges, lord-mayors, &c.; alſo large marble monuments to the juſtly eſteemed lord-mayor, Beckford, the great lord Chatham, &c. Beſides the hall, the following offices are included in the preſent building; chamberlain's-office, the court of king's bench, in which the lord-mayor's court and ſeſſions of the peace for the city are held; a court of common pleas, and court of exchequer; a court, called common council chamber, for the lord-mayor, aldermen, and common council. Attached to the Guildhall is an old chapel, which formerly belonged to a religious eſtabliſhment, but is now uſed as a juſtice-room for the aldermen.

The Bank of England, an immenſe pile of building, is more extenſive in its range of offices, and more eminent for its architectural adornment and interior arrangement, than any ſingle public edifice in the metropolis: for Somerſet-houſe, or place, conſiſts of various offices, dwelling-houſes, &c. It preſents an irregular and incongruous medley of ſtyles and forms; having been built at various periods by three different architects. The oldeſt part, *i. e.* the centre of the principal, or ſouth front, with ſome apartments on the ſame ſide, was deſigned and erected by George Sampſon, in the year 1733: and the lateral wings of this façade, and the returns on the eaſt and weſt ſides, with ſeveral offices immediately attached, were built by ſir Robert Taylor, between 1770 and 1786: but the great alterations and additions that have been made ſince the year 1788 by Mr. Soane, conſtitute the prominent features of this noble edifice. It would occupy a volume to deſcribe the whole arrangement and extent of the bank: it muſt ſuffice on the preſent occaſion to mention a few of its leading characteriſtics. The whole buildings are included in an area of an irregular form, the exterior wall of which meaſures 365 feet in front, or on the ſouth ſide; 440 feet on the weſt ſide; 410 feet on the north ſide, and 245 feet on the eaſt ſide. This area compriſes eight open courts, one rotunda, or circular room, ſeveral large public offices, committee rooms, and private apartments for the reſidence of officers and ſervants. The principal ſuite of rooms is on the ground-floor, and there is no floor over the chief offices; but it is neceſſary to ſtate, that beneath this floor, and even below the ſurface of the ground, there is more building, and more rooms than above-ground. Part of the edifice is raiſed on a marſhy, ſoft ſoil, for the ſtream called Wallbrooke ran here, and it has been neceſſary to pile the foundation, and conſtruct counter arches beneath the walls. The following is a liſt of the principal public rooms, with their dimenſions: on the ſouthern ſide, dividend-pay office, 44 by 40 feet; the three *per cent.* reduced office, 50 by 40 feet; pay-hall, 40 by 70 feet; ſtock-office, 60 by 45 feet: three others of nearly the ſame dimenſions; the rotunda, 55 feet in diameter; the conſol office, 80 feet by 48, is a noble room; court-room, 60 by 30 feet, ad-

joining which is the great committee room; office for notes under 5*l*., 60 by 40 feet; and the chief cashier's office, 45 by 30 feet. Besides these, the Bank contains many other offices and apartments: among which may be named the secretary's office, bullion office, deputy governor's rooms, general cash-book office, out-teller's office, land-tax redemption office, loan, or property office, drawing office, accomptant's office for the new specie, cheque office, reduced annuity office, dividend pay-office, armoury, bank-note printing-office, engraver's rooms, the library, &c. Such is the extensive business of the bank, that above 1000 persons are employed in its various offices. Of the architectural characteristics of this edifice, its extent, arrangement, and adaptation to the accumulated and increasing business of the British bank, it will be impossible to convey satisfactory information, in a limited space, and without illustrative prints. We can only briefly describe a few of the principal features. The oldest part by Sampson, combines a degree of simplicity united with grandeur; and was admirably adapted to its original purpose. It bespoke the character of a public edifice, with a rich and appropriate style of design. The whole assumed an air of dignity and importance, with a sufficiency of ornament and dress. On a rusticated basement are two stories with Ionic columns, and a bold entablature. An uniformity of character pervades the whole. With such a model before him, it is astonishing that sir Robert Taylor did not design his additions in the same style, or in one that harmonized with it: but it seems evident that he did not feel or appreciate the charms of simplicity. He preferred prettiness to propriety, and gaiety to grandeur, and therefore designed the wings, with the offices immediately attached, in the most gorgeous style of Roman architecture. Corinthian fluted columns, arranged in pairs, are placed along the whole front, supporting pediments at both extremities, and a balustraded entablature between.

In this façade, the architect has copied a building of Bramantes in the Belvidere gardens at Rome; but this very circumstance impeaches his taste and judgment. For though the style and design might have been appropriate and judicious in a small ornamental building, it is very absurd in a great national structure, where solidity, security, and simple grandeur were required. The four and five *per cent.* stock offices are truly disgusting, as works of art; and also very defective as rooms for business. They are both exact imitations of the interior of the church of St. Martin's-in-the-Fields. The forms and proportions of the exterior columns much excite our admiration. In the additions and improvements made to the bank by Mr. Soane, since his appointment in 1788, we find many novelties in design, and skilful appropriations. The rotunda is a spacious circular room, with a lofty dome; where a large and heterogeneous mass of persons of all nations and classes assemble on public days to buy and sell stock. The design and construction of the dome, by the last named architect, are entitled to the particular notice and admiration of strangers. In the three *per cents.* warrant office, the same profound artist has displayed much taste and skill. It is an oblong room, with a vaulted ceiling springing from ornamented piers; and in the centre is a handsome dome, or lanthorn light, supported by caryatides. The soffites of the arches are decorated with pannels, roses, and other objects in strict conformity to the practice of the ancient architects. It is worthy of remark, that the whole is constructed without timber. Branching from this apartment is another, called the interior office, adapted to clerks whose business is to guard against forgery. It opens to Lothbury court, which is a grand display of architectural design, two sides of it being formed by open screens, with handsome fluted columns of the Corinthian order. These are copied from the little temple at Tivoli. On the southern side of this court is a noble arch of entrance to the bullion court, and to other offices. This arch and façade are designed after the model of the celebrated triumphant arch of Constantine at Rome. On the sides of the great archway, are four handsome fluted columns, supporting an entablature, and four statues emblematic of the four quarters of the globe. In pannels are basso-relievi, executed by that great master of sculpture, Banks, allegorically representing the Thames and Ganges. The chief cashier's office is a noble apartment, in the design of which the architect has again shewn his enthusiastic attachment to classical antiquity. It is in imitation of the temple of the sun and moon at Rome, and is spacious, simple in decoration, and cheerfully lighted by large and lofty windows. In the accomptant's office, governor's court, vestibule and passage from Prince's-street, and recessed portico at the north-western angle, are some specimens of architectural design, which must excite the admiration of every accomplished connoisseur. In all these parts we recognize the forms, style, and detail of the best antique specimens, carefully adapted to their respective situations, and calculated to gratify the eye and satisfy the judgment. Stability is certainly the most essential object in such a building; but beauty and grandeur are equally deserving of attention; for the British bank is rich, its proprietors are presumed to be men of learning and science, and under their auspices we are entitled to look for such actions and such works as shall be ornamental and honourable to the character and taste of the kingdom. In the great enlargements that have been recently made in the present building, it is evident, that the architect has been particularly attentive to the immediate business of the company, the security of their property from fire and depredation, and a chaste, classical style of embellishment. These remarks and descriptions are the result of a recent examination of the building.

Places of Worship.—London is distinguished by the number and variety of its places of worship. It contains 116 churches of the established religion; above 80 chapels of ease on the establishment, in parishes where the population is too great for their respective churches; 11 Roman Catholic chapels; 17 churches and chapels belonging to foreign Protestants; six synagogues of the Jews; and 132 meeting-houses of the different denominations of English Protestant dissenters.

Of the 116 churches above-mentioned, 74 are within the walls of the city, 10 in London, without the walls, nine in the city and liberties of Westminster, five in the borough of Southwark, and 18 in the suburbs, not included in these classes. Of these we can only particularise a few; for descriptions of the whole would require a large volume. Pre-eminent above all the buildings of the metropolis, is the

Cathedral Church of St. Paul, which holds the most distinguished rank among the modern works of architecture in the British empire. The original cathedral was commenced in the year 610, by Ethelbert, king of Kent, and the building, with its revenues and privileges, were greatly increased by succeeding sovereigns. This structure was destroyed by a conflagration in 1086; after which, Maurice, then bishop, commenced the magnificent edifice which immediately preceded the present cathedral. So great was

the magnitude of the building, that neither Maurice, nor his fucceffor De Belmeis, were able to complete the undertaking, though each of them prefided twenty years, and expended great fums in the profecution of it; the latter prelate appropriated the whole revenue of his bifhopric to carrying on the work, and fupported himfelf and family by other means. After his death the building was for fome time fufpended, and the eaftern part, or choir, was burnt in the year 1135. At what period it was reftored is uncertain; the grand ceremony of confecration was performed in 1240; large additions were afterwards made to the ftructure, and it was not till the year 1315 that the church was entirely completed; being 225 years from the time of its foundation by Maurice. This ancient cathedral muft always be regarded as one of the great works of architecture of the middle ages; in dimenfions it far exceeded every other religious edifice in this country; and it is reprefented by hiftorians as equally pre-eminent in magnificence and fplendour of ornament. (For an account of this edifice, fee Dugdale's Hiftory of St. Paul's.) In the reign of James I., the cathedral having fallen to decay, a royal commiffion was iffued for its repair; but nothing of confequence was done till the advancement of Laud to the fee of London, in the fucceeding reign. This prelate exerted himfelf zealoufly in favour of the neglected building; a fubfcription was collected to the amount of 101,330*l.* 4*s.* 8*d.*; and Inigo Jones was appointed to fuperintend the undertaking. He commenced his operations in 1633; and the work went rapidly on till the breaking out of the civil war threw all things into confufion, and the parliament confifcated the unexpended money and materials. After the reftoration, the repairs were again commenced; but after much labour and expence, the great conflagration in 1666, deftroyed the chief part of the building, and irreparably damaged the remainder. Still, however, the magnitude of the work, and the contemplation of the vaft expence of building a new cathedral, occafioned a lapfe of feveral years before it was finally determined that all attempts at reparation were hopelefs. The impracticability of reftoring the ancient church being now apparent, Dr. (afterwards fir) Chriftopher Wren, was ordered to prepare plans for a new cathedral. The pulling down the remaining walls of the old ftructure, and the removal of the rubbifh to the amount of 47,000 loads, proved exceffively laborious as well as dangerous, and feveral men were killed in the progrefs of the work. This being completed, the firft ftone of the new edifice was laid June 21, 1675; and the defign was profecuted with fuch diligence and fuccefs, that within ten years the walls of the choir and fide aifles were finifhed, together with the circular porticoes on the north and fouth fides. The laft or higheft ftone of the building was laid at the top of the lantern in the year 1710; and fhortly afterwards the queen and both houfes of parliament attended divine fervice in the new cathedral. The whole ftructure was thus completed in thirty-five years, by one architect, fir Chriftopher Wren, and one mafter mafon, Mr. Thomas Strong, and while one prelate, Dr. Henry Compton, filled the fee of London.

The general form or ground plan of St. Paul's cathedral is that of a Latin crofs, with an additional arm or tranfept at the weft end, to give breadth to the principal front, and a femicircular projection at the eaft end for the altar. At the extremities of the principal tranfept are alfo femicircular projections for porticoes; and at the angles of the crofs are fquare projections, which, befides containing ftaircafes, veftries, &c. ferve as immenfe buttreffes to the dome, which rifes from the interfection of the nave and tranfept, and is terminated by a lantern, furmounted by a ball and crofs of copper gilt. The weft front of this fabric confifts of a noble portico of two orders, the Corinthian and the Compofite, refting on a bafement formed by a double flight of fteps, of black marble, and furmounted by a fpacious pediment. On each fide is a tower, with columns, &c.; one ferving as a belfrey, the other as the clock-tower. In the tympan of the pediment is a very large piece of fculpture, in baffo-relievo, of the converfion of St. Paul; and on the apex a gigantic ftatue of the fame apoftle; whilft on either hand, along the fummit of the front, are other coloffal ftatues of St. Peter, St. James, and the four evangelifts. Large ftatues of the other apoftles are placed upon pediments on the fide walls of the fabric. The dome is the moft remarkable and magnificent feature of the building. It rifes from a circular bafement, which, at the height of about twenty feet above the roof of the church, gives place to a Corinthian colonnade, formed by a circular range of thirty columns. Above the colonnade, but not refting upon it, rifes an attic ftory with pilafters and windows, from the entablature of which fprings the exterior dome, which is covered with lead, and ribbed at regular intervals. Round the aperture, at its fummit, is another gallery; and from the centre rifes the ftone lantern, which is furrounded with Corinthian columns, and crowned by the ball and crofs.

In its interior form, this edifice is entirely conftructed on the plan of the ancient cathedrals, *viz.* that of a long crofs, having a nave, choir, tranfepts, and fide aifles; but, in place of the lofty tower, the dome in this building rifes in elevated grandeur from the central interfection. The architectural detail is in the Roman ftyle, fimple and regular. The piers and arches, which divide the nave from the fide aifles, are ornamented with columns and pilafters of the Corinthian and Compofite orders, and are further adorned with fhields, feftoons, chaplets, cherubim, &c. The vaulting of this part of the church merits great praife for its light and elegant conftruction: in this, each fevery forms a low dome, fupported by four fpandrils; the bafe of the dome being encircled by a rich wreath of artificial foliage. The central area below the dome deferves particular attention: this is an octagon, formed by eight maffive piers, with their correlative apertures, four of which, being thefe that terminate the middle aifles, are forty feet wide, while the others are only twenty-eight; but this difparity only exifts as high as the firft order of pilafters, at which level the fmaller openings are expanded in a peculiar manner, fo that the main arches are all equal. The fpandrils between the arches above form the area into a circle, which is crowned by a large cantilever cornice, partly fupporting by its projection the "whifpering gallery." At this level commences the interior tambour of the dome, which confifts of a high pedeftal and cornice, forming the bafement to a range of apparently fluted pilafters of the Compofite order, the intervals between which are occupied by twenty-four windows and eight niches: all this part is inclined forward, fo as to form the fruftum of a cone. Above, from a double plinth, over the cornice of the pilafters, fprings the internal dome; the contour being compofed of two fegments of a circle, which, if not interrupted by the opening beneath the lantern, would have interfected at the apex. The dome, the idea of which was confeffedly taken from the pantheon at Rome, is of brick, two bricks thick; but, as it rifes, at every five feet has a courfe of brick, of eighteen inches long, bending through the whole thicknefs: for greater fe-

curity alfo, in the girdle of Portland ftone which encircles the low part, an enormous double chain of iron, ftrongly linked together, and weighing nearly 96 *cwt.*, was inferted in a channel, which was afterwards filled up with lead. Over this cupola is a cone of brick, fo built as to fupport a ftone lantern of an elegant figure. The choir is of the fame form and architectural ftyle as the body of the church.

The dimenfions of this vaft fabric are, height from the ground without to the top of the crofs 340 feet, extreme length within 500 feet, greateft breadth 223 feet. The entire afcent to the ball includes 616 fteps. The weight of the ball, which is capacious enough to contain eight perfons, is 5600 lbs.; and that of the crofs, 3360 lbs. For a more particular defcription of this edifice, with plan of the fubftructure, elevation of the weft front, fection of the dome, and north-eaft view of the exterior, fee "Fine Arts of the Englifh School," 4to. 1812.

The particular objects of curiofity which are comprifed in this church, and generally fhewn to ftrangers, are the whifpering gallery, which encircles the interior of the lower part of the dome, and is fo conftructed, that a low whifper breathed againft the wall, in any part of the circle, may be heard on the oppofite fide; the library, chiefly remarkable for the floor, which is conftructed with fmall pieces of oak, difpofed in geometrical figures; the beautiful model, conftructed by fir Chriftopher Wren; the geometrical ftaircafe, the fineft fpecimen of the kind in Great Britain; the clock, and great bell on which it ftrikes. The clock is of great magnitude: the length of the minute-hand is eight feet, and its weight 75 lbs.; the hour-hand five feet four inches, and its weight 44 lbs.; the diameter of the dial is eighteen feet ten inches; the length of the hour-figures two feet two inches and a half; the bell is about ten feet in diameter, and its weight nearly four tons and a quarter.

About the year 1790 a fcheme was fuggefted, and has been happily carried into effect, for breaking the monotonous uniformity of the architectural maffes in the interior of the cathedral. This was done by admitting large and noble monuments for eminent public perfons deceafed. Thefe may with ftrict propriety be termed *national*, as commemorative of Britifh virtues, talents, or heroifm. Statues are already erected for Mr. Howard the philanthropift, Dr. Johnfon, and fir William Jones. Here are alfo monuments for generals Abercromby and Dundas, and for captains Moffe, Riou, Weftcott, Burgefs, and Faulknor. Others are now erecting for marquis Cornwallis, lord Howe, and lord Nelfon. The latter is interred in the vault under the centre of the building; and near him, his friend lord Collingwood. Among other eminent characters who have been depofited in thefe vaults, are fir Chriftopher Wren; Dr. Newton, late bifhop of Briftol; Alexander Wedderburn, earl of Rofslyn; fir John Braithwaite; fir Jofhua Reynolds, prefident of the Royal Academy; and two other eminent artifts, James Barry and John Opie, efqrs.

Although the churches in London are moftly plain, ordinary in architecture, and in obfcure fituations, yet a few of them are entitled to the notice and admiration of a ftranger. That of St. Stephen Walbrooke, built by fir Chriftopher Wren, is very fmall, but is juftly efteemed for its novelty of defign and architectural adornment. "The plan is original, yet fimple; the elevation furprifing, yet chafte and beautiful; the dome, fupported by eight arches, fpringing from eight fingle columns, is wonderfully light and fcenic in its effect." (Malton's Picturefque Tour, p. 76.) Over the altar is a fine picture reprefenting the interment of St. Stephen, by Weft. The following churches and towers have claims to architectural beauty, or fcientific merit. The tower and fpire of Bow-church, in Cheapfide, by fir Chriftopher Wren; the tower of St. Michael's, in Cornhill; the tower and fpire of St. Bride's, in Fleet-ftreet; the church of St. Mary, called the New church, in the Strand, by James Gibbs; the church of St. George, in Bloomfbury, by N. Hawkfmoor, built in 1731; the tower and fpire of St. Dunftan in the Eaft, by fir Chriftopher Wren; and the church of St. Paul, Covent Garden, by Inigo Jones.

Members of Parliament.—The city of London has no more weight in the legiflative reprefentation of the kingdom, than two fmall boroughs which are the property of an individual. It fends four reprefentatives to parliament, who are chofen, not by the inhabitant houfeholders at large, but by the livery of the feveral companies. The right of election was anciently vefted in the freemen of the city, which gave rife to many contefts between the freemen and livery; till an act of parliament, paffed in the eleventh year of George I., decided the queftion, and gave a peremptory right to the livery only. To be poffeffed of this elective franchife, a man muft have previoufly obtained his freedom of the city, and alfo of one of the trading companies, either by patrimony, fervitude, or purchafe; and muft afterwards be admitted to the livery of his company. The prefent number of electors is about eight thoufand, which is not above a third part of the number of inhabitant houfekeepers. The elections are held in Guildhall, and the fheriffs are the returning officers. The city fent two members to parliament as early as 49 Henry III. The number was increafed to four, 6 Edward II.: in that and the fucceeding reign, four were frequently fent; but fince 43 Edward III., this number has been uniformly returned.

Inns of Court and Chancery.—The defign of thefe eftablifhments having been curforily noticed under INNS, it may be proper here to fubjoin fome further particulars relative to each. The inns of court in London are the Inner Temple, the Middle Temple, Lincoln's Inn, and Gray's Inn; but there are feveral other places called inns, which are appendages to the former. The Temple, belonging to the two focieties of the Inner and Middle Temple, is an immenfe affemblage of buildings, extending from Fleet-ftreet to the Thames; and from Lombard-ftreet, White-friars, to Effex-ftreet in the Strand. It derives its name from a religious houfe, which was founded by the Knights Templars, who were crufaders; and, in the beginning of the twelfth century, formed themfelves into a military body at Jerufalem, for the protection of the pilgrims who vifited the holy fepulchre. On the diffolution of the order, the Temple was granted to the Knights Hofpitallers of St. John of Jerufalem; and by them it was let for 10*l.* *per annum* to the ftudents of the law, whofe fucceffors ftill poffefs it. (See HOSPITALLERS and TEMPLARS.) The Temple is an irregular building: in Fleet-ftreet are two entrances, one to the Inner and one to the Middle Temple; the latter has a front, in the ftyle of Inigo Jones, of brick, ornamented with four large ftone pilafters, of the Ionic order, with a pediment. There are four other entrances; but the gates of all are fhut at night. The garden of the Inner Temple is of great extent, and is laid out on the banks of the Thames, with fpacious walks, &c. The Middle Temple has alfo a garden, but fmall: both are open to the public in fummer. The hall of the Middle Temple is a fpacious and curious room: the Inner Temple hall, which is fmaller, is orna-

mented with the portraits of ſeveral of the judges. Each ſociety has a good library for the uſe of its ſtudents. In the treaſury chamber of the Middle Temple is preſerved a great quantity of ancient armour, which belonged to the Knights Templars. The Temple church belongs in common to both ſocieties, and is open for divine ſervice twice every day. The Knights Templars built a church on this ſcite, which being deſtroyed, the preſent edifice was erected by the Knights Hoſpitallers. It is in the early pointed and late circular ſtyles of architecture, and conſiſts of two diſtinct parts: at the weſtern end is a ſpacious round tower or veſtibule, forming a grand and ſingular entrance to the church. In this are the ſtatues of eleven Knights Templars. The organ is eſteemed one of the fineſt in the world. Since the time of Henry VIII. the ſuperior clergyman of this church is called the maſter of the Temple, and is ſo conſtituted by the king's letters patent. For an account of this church, with ground plan and prints, ſee Britton's Architectural Antiquities of Great Britain, vol. i.—Lincoln's Inn is ſituated on the weſt ſide of Chancery-lane. On its ſcite anciently ſtood a houſe of the Black-friars, and the palace of the biſhops of Chicheſter. The ground was afterwards granted to Henry Lacy, earl of Lincoln, from whom it derives its name. It appears to have reverted to the biſhops; for the preſent poſſeſſors hold it as a grant from a prelate of that ſee. Lincoln's Inn occupies a very extenſive ſpace: the buildings are moſtly old and irregular. An attempt has been made, but never completed, to rebuild the Inn on a regular plan. A conſiderable range, called the Stone Buildings, faces the weſt. This plan, the work of ſir Robert Taylor, is ſimple and elegant in its exterior architecture; and the chambers are on a grand and commodious ſcale. In the old part of the building are the hall and chapel; the firſt of which is a ſpacious room, in which the lord chancellor holds ſeals and ſittings out of term. At the upper end is a painting by Hogarth, of St. Paul before Felix. The chapel, deſigned by Inigo Jones, is ſpacious, and raiſed on large piers and arches, which form an open area beneath, uſed as a burial-place for benchers only. The chapel is open for public worſhip every morning and evening. The garden, which in ſummer is open to the public, is ſpacious, and forms one of the fineſt promenades within the capital. Lincoln's Inn has a good library, which contains a great number of manuſcripts; the greater part of which was bequeathed by lord Hale, with a ſingular injunction, that no part ſhould ever be printed. Gray's Inn is ſituated on the north ſide of Holborn, and derives its name from a lord Gray, who reſided here. In this Inn is a ſmall neat chapel, a commodious hall, and an extenſive garden, with a grove of large elm trees. The inns of chancery, which are dependent on the inns of court, are Furnival's Inn, an appendage to Lincoln's Inn: it is ſituated on the north ſide of Holborn-hill, and was the manſion of ſir William le Furneval, in the time of Richard II.—Thavies Inn, alſo dependent on Lincoln's Inn: the old fabric having been recently burnt down, a neat range of buildings is erected on its ſcite, which is near St. Andrew's church, Holborn.—Staple Inn, ſituated on the ſouth ſide of Holborn, and an appendage to Gray's Inn: in the hall are caſts of the twelve Cæſars, and portraits of Charles II., queen Anne, lord Macclesfield, and the lords chancellors Cowper and Camden.—Barnard's Inn, ſituated near Fetter-lane, Holborn, and a dependent on Gray's Inn.—Serjeant's Inn, in Chancery-lane: it has a ſmall neat chapel, with ſeats for the judges.—Clifford's Inn, ſituated near St. Dunſtan's church, Fleet-ſtreet, and an appendage to the Inner Temple: in the hall is an oak caſe, of very great antiquity.—Clement's Inn, near St. Clement's church in the Strand, a dependent on the Inner Temple: it contains an elegant hall, and a garden kept with particular care, in which is a ſun-dial, ſupported by a kneeling figure of conſiderable merit, brought from Italy by lord Clare.—New Inn, adjoining to the laſt mentioned, and an appendage to the Middle Temple.—Lyon's Inn, ſituated in Wych Street, and belonging to the Inner Temple. For hiſtorical and deſcriptive particulars of theſe eſtabliſhments and buildings, the reader is referred to Dugdale's "Origines Juridiciales," folio, 1680; Herbert's "Antiquities of the Inns of Court and Chancery," 8vo. 1804; and Lane's "Student's Guide to Lincoln's Inn," 8vo.

General remarks.—Before cloſing this intereſting and important article, it ſeems proper to offer a very few remarks on the characteriſtic features of the metropolis, the manners and condition of its inhabitants, and the local peculiarities by which it is diſtinguiſhed. Such obſervations, however, the reader will readily perceive muſt be extremely general indeed. The ſubject is too various and comprehenſive to admit of full developement in a ſection, ſuch as the nature and limits of a work of this kind neceſſarily preſcribe.

The vaſt extent of London, and its immenſe population, cannot fail to ſtrike every viſitor with wonder and aſtoniſhment. Even to thoſe who have previouſly reſided in Paris, or in any other large city, theſe circumſtances alone muſt be matter of ſurpriſe; for not only is this city far more extenſive than the imperial metropolis, but it contains at leaſt 400,000 more perſons. Theſe, like the inhabitants of all great trading cities, are a heterogeneous maſs, compoſed of foreigners from every town and province of the united kingdoms, with a large portion of Jews, both native and foreign, Indians, Germans, French, Italians, Spaniards, Swiſs, and people of almoſt every nation in the world. From its immenſe trade, foreign and internal, a conſtant communication is kept up with every part of the globe, as well as with every part of our own dominions, both at home and abroad. The quantity of property of every deſcription flowing into the metropolis, and diſtributed from it, is immenſe. The number of ſtrangers conſtantly here, either on buſineſs or for pleaſure, is ſuppoſed to be not leſs than 100,000. Hence the prodigious concourſe of people in the ſtreets, and the number of carriages, carts, and other vehicles, continually crowding through them, are unparalleled in any city in the world

London, in its uſual and more extenſive application, contains two cities, London and Weſtminſter, beſides the borough of Southwark. The city of Weſtminſter was formerly entirely detached from London, for the ſtreet now denominated the Strand was, at no very diſtant period, a ſort of bog, or moraſs, by which they were ſeparated. The monarchs of England have, for ſeveral centuries, fixed upon this city as their court reſidence, and the ſeat of the legiſlative and judicial authorities. This portion of modern London and its ſuburbs have extended with more rapidity than any other diſtrict of the town. Its buildings are in a much ſuperior ſtyle of architecture, and more open and regular in their diſtribution and arrangement, than thoſe in the city of London. They are chiefly inhabited by the nobility, gentry, and higher claſs of merchants, and though perhaps even inferior in external appearance to the reſidences of the nobles in ſome other countries, are no where ſurpaſſed in internal ſplendour and magnificence. London, within the walls, is the great repoſitory of the mercantile

wealth, not merely of the metropolis, but of the whole country. Hence the buildings themselves bear ample testimony to the object for which they were raised. Almost every house is a shop, or a counting-house, and so closely are they huddled together, that in many places room is scarcely left for the passage of a single cart. Ground is valuable, and is fully occupied. This renders it certainly a matter of regret, and the remark is applicable to every part of the town, that there exist no regulations, or general plan authorized by act of parliament, to which all builders should be obliged to conform. Such a plan, it is believed, was suggested by sir Christopher Wren after the great fire in 1666, and since by Gwynn, in a quarto volume, entitled "London and Westminster improved, &c."

In a political point of view, London bears a most important sway in deciding the opinions of the country at large. It is the centre from which all information, civil or military, emanates. The number of newspapers and other political vehicles distributed here, and hence over the united kingdom, is prodigiously great. The foreigner who peruses a few of these, cannot but be astonished at the opposite sentiments they contain, and the freedom with which they praise or censure the measures of government. This is the consequence of liberty, and is doubtless one of its chief supports. The ruling magistrate of the kingdom is not exempt from public censure and critical animadversion. At the commencement of the year 1812, this is more notorious than at any former period; and future historians will have occasion to explain the cause and lament the effect. Not only has London a powerful influence over the political sentiments of the country, but it has likewise no inconsiderable share in directing the conduct of the higher powers. This it effects in some degree by the members it returns to parliament, which are six in number, but much more by the influence and riches of some of its chartered companies, as well as individuals. The bank of England, mostly a body of merchants, is closely identified with government. The minister is compelled to have recourse to the citizens for supplying the deficiences in the revenue, by loan, all which circumstances render it necessary for the government to pay peculiar attention to the interests of the city in general.

London may further be characterized as the grand theatre for the display of talents either in the arts or sciences. It is here alone, perhaps, of all the cities in the united kingdom, that literary ability will receive any adequate reward. The artist of genius will likewise in general meet here with support and encouragement. He will here find the finest productions of the most celebrated masters in every department of art, by the study of which alone it is possible for him to attain the praise of excellence. In London are to be seen the best actors, and the most splendid theatres, Great Britain can boast of. The talents of the vocal and instrumental performers at the opera and concerts are unrivalled, and probably no city in Europe possesses a place of public amusement more brilliant and magnificent than Vauxhall. London likewise abounds with museums, also various scientific, literary, and rational establishments.

The merchants, bankers, and higher classes of tradesmen, bear a strong resemblance in manners to the gentry with whom, from their immense wealth, they are generally accustomed to associate. The same wealth, and the greater security they possess for its enjoyment than the merchants of other countries, confer upon them a spirit of real independence, to which the latter are totally strangers. From this spirit of independence many advantages have undoubtedly arisen both to the political condition and commercial prosperity of England. Reacting as it were upon the springs of our free constitution, from which it proceeds, it tends to render them vigorous and effective. Britons justly boast of their trial by jury as the bulwark of their freedom, but of what use would juries be, if the individuals who compose them were dependent and submissive. It is to the spirit of the people rather than to any particular forms of administration that a country is indebted for its freedom.

The nobility and gentry of London are of a very different complexion from the same classes in other countries. They possess the highest polish of manners, but unite with their accomplishments a degree of manliness and moderation, the result of the freedom of the English constitution and the general diffusion of riches. A foreign nobleman considers himself as a distinct species of being from those who are his inferior in rank and station, and consequently treats them with arrogance and contempt. An English nobleman, on the other hand, while sufficiently conscious of his own superiority, behaves towards those whom fortune has placed beneath him with real attention and civility; even in the article of dress he is scarcely to be distinguished from the ordinary tradesman or mechanic, while the higher class of merchants fully equals him in the splendour of his equipages and establishments. He is almost wholly a stranger to that indolence which usually results from excessive wealth and hereditary titles. Even the ladies of high rank are much less enervated and feeble than most of the same class abroad. They are accustomed to much exercise, and to mix in the public world.

The beneficial operation of this spirit on our commerce is the consequence of that honour and integrity, which are uniformly found to accompany elevation of mind. That honesty is the best policy, has long been an undisputed dogma in commercial transactions in London. Hence it is that an English merchant can often obtain credit even in foreign countries, where it is little practised, and bills of immense value are sometimes entrusted to him without receipt or acknowledgment. But these remarks ought not to be considered as applicable to the higher orders of traders only. The same freedom of conduct and sterling integrity are prominent features in the character of the generality of established shop-keepers, particularly those of the city.

With respect to physicians, surgeons, and barristers, they may be ranked with the gentry, though influenced by some little peculiarity of habits and manners. Apothecaries and attornies may be classed with the better sort of shop-keepers.

The labouring classes in London are usually of industrious and frugal habits. Their dress and appearance are far more decent and respectable than in any other city in the world. and this alone is a sufficient evidence of its great trade and wealth. The same thing may be said of the poorer sort of shop-keepers, who, from the rate of their earnings, may be placed in the rank of labouring people. Male and female servants, in plain and honest families, may likewise be thrown into this rank with a similar character.

Among many essential improvements recently made in London, the following are worthy of notice and commendation. In the city, and at the east end of the town, we find that new docks have been made on a vast scale, whereby

the property of merchants, companies, and the government is, and will be, materially benefited. Many commodious ftreets and new houfes have alfo been made in the vicinity of thofe docks, fo that from the Tower to Limehoufe a new town has been formed. All the great roads leading to London have been much improved, and every approach to the metropolis, excepting that through the Borough, is broad, good, and flanked by handfome rows of houfes, or detached villas. In the city, and immediately adjacent, a wide and handfome ftreet, called Skinner-ftreet, has been entirely new built; a handfome fquare formed in Moorfields, other ftreets made near Temple Bar, feveral new buildings erected around the Bank, and others on Tower-hill. In Mary-le-bone a new plan is executing of laying out a large park into various allotments of detached villas, with gardens and pleafure grounds, by John Nafh, efq. architect. The deftruction of the two great theatres by fire has afforded opportunities for much improvement, and much has been effected. North of Holborn many new fquares and ftreets have been built, the greater part of which has been defigned by James Burton, efq. In fubfequent accounts of MARY-LE-BONE, PADDINGTON, and WESTMINSTER, many other fubjects will be defcribed.

Publications relating to London and Weftminfter.—Though many volumes have been exprefsly devoted to the hiftory and topography of the metropolis, it is generally admitted, and much to be regretted, that not one work is fatisfactory either as a comprehenfive hiftory, or popular and general defcription. The moft elaborate, and the moft complete at the time of publication, is Strype's edition of Stow's "Survey of London," 2 vols. folio, fixth edition, 1754: but this is merely a reprint of a former edition of 1720. As a fort of guide, or popular account of the prefent metropolis, "The Picture of London for 1812," called "the thirteenth edition," is beft adapted to furnifh a ftranger with a view of London 'as it is': but this, though admirably planned, and well executed in parts, is replete with errors of names, dates, and events. Many of its ftrictures are objectionable on points of art, tafte, and antiquities; and one fection on reviews and literary criticifm is unjuft, and of injurious tendency. The moft effential points of thefe two works, with much additional information, will be comprifed in Brayley's "London and Middlefex; or, An hiftorical, commercial, and defcriptive Survey of the Metropolis of Great Britain," now in the progrefs of publication, and promifed to be completed in two large octavo volumes. The following are the titles of the other principal works relating to the topography of the metropolis.

"The Hiftory of London, from its Foundation by the Romans, to the prefent Time," by William Maitland, F.R.S. and others, 2 vols. folio, 1765.

"A new and complete Hiftory and Survey of the Cities of London and Weftminfter, the Borough of Southwark, and Parts adjacent," to the year 1770, by Henry Chamberlain, efq. and a fociety of gentlemen.

"A new Hiftory of London, including Weftminfter and Southwark," by John Noorthouck, citizen and ftationer, 4to. 1773.

"Repertorium Ecclefiafticum," by —— Newcourt, 2 vols. folio. 1708.

"Londinopolis, or An hiftorical Difcourfe of the City of London," by Howell, folio, 1657.

"A picturefque Tour through the Cities of London and Weftminfter," by Thomas Malton, folio, 1792.

"Londinium Redivivum, or An ancient Hiftory and modern Defcription of London," by James Peller Malcolm, F.S.A. 4 vols. 4to. 1807.

"Some Account of London," by Thomas Pennant, efq. 4th edition, 4to. 1805.

"The Cuftoms of London, otherwife called Arnold's Chronicle," new edit. 4to. 1811.

"London; being an accurate Hiftory and Defcription of the Britifh Metropolis, and its Neighbourhood," 6 vols. 8vo. faid to be by David Hughfon; but really compiled and written by David Pugh. This mode of giving fictitious names is very reprehenfible.

"London and Weftminfter improved, with a Difcourfe on public Magnificence," by John Gwynn, 4to. 1766.

"A critical Review of the public Buildings, Statues, and Ornaments, in and about London and Weftminfter," by —— Ralph, architect, a new edition, 12mo. 1783.

"A Treatife on the Police of the Metropolis; containing a Detail of the various Crimes and Mifdemeanors by which public and private Property and Security are injured; and fuggefting Remedies for their Prevention," by P. Colquhoun, L.L.D. 8vo. Several editions have been publifhed.

"A Treatife on the Commerce and Police of the River Thames; containing an hiftorical View of the Trade of the Port of London, and fuggefting Means for preventing Depredations thereon, &c. With a Map of the River from London Bridge to Sheernefs," by P. Colquhoun, L.L.D. 8vo.

"A Treatife on the Functions and Duties of a Conftable; containing interefting Details and Obfervations, relative to the Corruptions of Morals, and the Protection of the peaceful Subjects againft penal Offences," by P. Colquhoun, L.L.D. 8vo.

"The Thames; or, Graphic Illuftrations of the Seats, Villas, &c. on the Banks of that River," 2 vols. 8vo. 1811. chiefly a book of prints.

"The Hiftory of London and its Environs," 2 vols. 4to. publifhed by John Stockdale.

It appears from Mr. Kirwan's "Eftimate of the Temperature of different Latitudes," that from a mean of the obfervations made at the houfe of the Royal Society, from the year 1772 to 1780, the annual temperature of London is 51°.9, or in round numbers 52°; the monthly temperature is ftated in the following table:

January	-	35.9°	July	-	66.3°
February	-	42.3	Auguft	-	65.85
March	-	46.4	September	-	59.63
April	-	49.9	October	-	52.81
May	-	56.61	November	-	44.44
June	-	63.22	December	-	41.04

The greateft ufual cold is 20°, and happens in January; the greateft ufual heat is 81°, and happens generally in July. The limits of the annual variation are 2°.5, that is, 1° above and 1°.5 below the mean.

The greateft variations of the mean temperature of the fame month, in different years, are as follows:

January	-	6	July	-	2
February	-	5	Auguft	-	2
March	-	4	September	-	3.5
April	-	3	October	-	4
May	-	2.5	November	-	4
June	-	2	December	-	3

Hence it appears that the ſummers differ much leſs than the winters.

The moſt uſual variations of temperature within the ſpace of 24 hours in every month, are

	°		°
January -	6	July -	10
February -	8	Auguſt -	15
March -	20	September -	18
April -	18	October -	14
May -	14	November -	9
June -	12	December -	6

Hence is ſeen the origin of vernal and autumnal colds.

Mr. Kirwan has ſhewn that, proportionably to its latitude, it is much colder in London than at Edinburgh; for the mean temperature of Edinburgh in January is 34° 5, and that of London is 35 9; and this difference he aſcribes to the following cauſes: 1ſt. That Edinburgh is not expoſed to the Siberian winds as London is. 2dly. That Edinburgh is nearer to the ſea. 3dly. The rigour of the northerly winds is very little moderated, if not increaſed, in paſſing from Scotland to us, particularly if the ſurface of the earth is covered with ſnow; and hence, if we believe Dr. Smollet (Travels to Italy), the winters are ſometimes milder at Edinburgh than at London.

LONDON, a town of America, in Ann-Arundel county, Maryland; 5 miles S.W. of Annapolis.

LONDON, *The townſhip of*, is ſituated in Upper Canada, on the main fork of the river Thames, is a central poſition from the lakes Erie, Huron, and Ontario, and offers many advantages for being the capital of the province. It communicates with lake St Clair and the Detroit by the river Thames; with lake Huron by the northern branch of the Thames and a ſmall portage, and with the Ouſe and lake Ontario by the military way called Dundas-ſtreet. It abounds with black and white walnut, cherry, baſs, elm, hickory, beech, aſh, and many other kinds of timber. It is ſupplied with excellent water, and the ſituation is healthy.

Looking-glass

LOOKING-Glass, a plain polished glaſs ſpeculum, or mirror, to one ſide of which a plate of tin-foil is made to adhere by means of quickſilver; which being impervious to the light, reflects its rays, and ſo exhibits the images of objects placed before it.

In conſequence of this conſtruction, the looking-glaſs makes a double reflection of every object, *viz.* one from the upper ſurface, which is the weakeſt, and another from the under ſurface, which is contiguous to the tin-foil. When a perſon ſtands juſt before the glaſs, the two reflections coincide, and he perceives one image; but if he ſtands oblique, as at A, (*Plate* IX. *Optics*, *fig.* 10.) and views the reflection D, of an object B C, ſituated on the other ſide, he will then perceive two images, *viz.* one cauſed by the upper, and the other cauſed by the lower ſurface of the glaſs E F. If the object B C be very luminous, ſuch as a lighted candle, then the eye at A will perceive a great ſucceſſion of candles at D, gradually decreaſing in ſplendour; the cauſe of which phenomenon is, that the ſtrong reflection from the under ſurface of the glaſs is again reflected from the upper ſurface, and this again by the lower, &c.

The theory of looking-glaſſes, and the laws whereby they give the appearance of bodies, ſee under Mirror.

Looking-*glaſſes, the manner of grinding and preparing*, is as follows: a plate of glaſs is fixed to a horizontal table of free-ſtone or wood, of about the ſame ſize, and cemented to it by Paris plaſter; and to another leſſer table is fixed in the ſame manner another plate. Over the firſt plate is ſprinkled fine ſand and water, in a ſufficient quantity for the grinding, and the ſecond or leſs plate is laid on it; and thus worked this way and that way, till each has planed the other's ſurface. Theſe plates are made to rub againſt each other evenly and ſteadily by a kind of hand-mill, the wheel of which is wrought by a man, or if the plates be large by two men, who regulate the preſſure as they think proper. As they begin to become ſmoother, finer ſand is ſucceſſively uſed. When one ſide of the plate is finiſhed, the plaſter that cemented it is picked off, and the plate turned, ſo that the other ſide may be ground in the ſame manner. Towards the cloſe of the operation of grinding, the preſſure is increaſed by loading the upper plates with flat ſtones of different thickneſſes. This proceſs laſts about three days, and it is of great importance that the ſurfaces ſhould be perfectly flat and parallel, which is determined by the ruler and plumb-line. In order to complete this proceſs, emery of different fineneſſes is uſed, and great care is taken in ſeparating and ſorting them. This is done by putting into a veſſel of water a quantity of rough emery, and well ſtirring it: the coarſeſt particles will ſink to the bottom, and the finer will be held ſuſpended for ſome time by the ſupernatant liquor. This liquor is poured off, and after ſome time, about 20 minutes, the finer particles will ſubſide. More water is then added to the veſſel, and the emery ſtirred again; and after remaining at reſt about 15 minutes, the ſupernatant liquor is poured off; and this by reſt furniſhes an emery of the ſecond degree of fineneſs. The ſame operation is repeated twice more at the different intervals of about five minutes and half a minute; by which two other ſorts are obtained. The wet emery obtained from all theſe liquors is ſeparably heated over a ſtove to evaporate the water, and when nearly dry, is made up into balls for the further operation. The plates are then ground on both ſides with two or three emerys, beginning with the coarſeſt, and finiſhed with great care. They are now perfectly even, and the ſcratches, which after the firſt operation remained and rendered them almoſt opaque, diſappear. (See Grinding.) For the method of poliſhing looking-glaſſes and mirrors, we refer to the article Polishing.

The plates being poliſhed, a thin blotting paper is ſpread on a table or marble ſlab; and ſprinkled with fine powdered chalk; and this done, over the paper is laid a thin lamina or leaf of tin, on which is poured mercury, which is to be equally diſtributed over the leaf, with a hare's foot or cotton. Over the leaf is laid a very thin ſmooth paper, of which the kind called fan-paper is beſt, and over that the glaſs plate. With the left hand the glaſs-plate is preſſed down, and with the right the paper is gently drawn out; which done, the plate is covered with a thicker paper, and loaden with a greater weight, that the ſuperfluous mercury may be driven out, and the tin adhere more cloſely to the glaſs. When it is dried, the weight is removed, and the looking-glaſs is complete.

Some uſe an ounce of mercury with half an ounce of marcaſite or biſmuth, melted by the fire; and left the mercury evaporate in ſmoke, pour it into cold water; and when cold, ſqueeze it through a cloth or leather. Some alſo add a quarter of an ounce of lead and tin to the marcaſite, that the glaſs may dry the ſooner. For more particular directions in the conduct of this operation, ſee SILVERING.

In the Phil. Tranſ. N° 245, we have a method of *foliating* (ſee FOLIATING) globe looking-glaſſes, communicated by ſir R. Southwell. The mixture is of quickſilver and biſmuth, of each three ounces, and tin and lead, of each half an ounce; to the laſt throw in the marcaſite, and afterwards the quickſilver; ſtir them well together over the fire; but they muſt be taken off, and be towards cooling before the quickſilver be put to them. When the mixture is uſed, the glaſs ſhould be well heated, and very dry; but it will do alſo when it is cold, though beſt when the glaſs is heated.

Mr. Boyle's method, which he prefers to any which he ever met with in print, is this: take tin and lead, of each one part, melt them together, and immediately add of good tin-glaſs, or biſmuth, two parts; carefully ſkim off the droſs; then take the crucible from the fire, and before the mixture grows cold, add to it 10 parts of clear quickſilver, and having ſtirred them well together, keep the fluid in a new clean glaſs. When you are going to uſe it, firſt purge it by ſtraining it through linen, and gently pour ſome ounces into the glaſs to be foliated through a narrow paper funnel, reaching almoſt to the glaſs, to prevent the liquor from flying to the ſides. After this, by dextrouſly inclining the glaſs every way, endeavour to faſten it to the internal ſurface; which done, let it reſt for ſome hours; then repeat the ſame operation, and ſo continue at times, till the liquor is ſlowly paſſed over, and equally fixed to the whole ſuperficies; which may be diſcerned by expoſing the glaſs to the eye between that and the light. Boyle's works abr. vol. i. p. 129.

For the method of blowing and caſting glaſs, and the choice of the materials for looking-glaſſes, ſee GLASS.

Machine

MACHINE, in a general ſenſe, ſignifies any thing that is uſed to augment or to regulate moving forces or powers; or, it is any inſtrument employed to produce motion, ſo as to ſave either time or force. The word is derived from *μηχανη*, *machine*, *invention*, *art*; and is therefore properly applied to any agent in which theſe are combined, whatever may be the ſtrength or ſolidity of the materials of which it is compoſed. The term machine, however, is by common uſage generally reſtricted to a certain claſs of agents, which ſeem to hold a middle place between the moſt ſimple *organa*, commonly called tools or inſtruments, and the more complicated and powerful, termed *engines*. This diſtinction, however, does not enter into the preſent article; we ſhall conſider machines under two heads, *ſimple* and *compound*. To the firſt claſs belong the *lever*, the *inclined plane*, the *ſcrew*, the *wedge*, the *wheel* and *axle*, and the *pulley*, commonly called the ſix mechanical powers; though ſome authors will only allow the lever, and the inclined plane, to be ſimple machines, the others being compounded of thoſe two.

Compound machines are all ſuch as conſiſt of a combination of the ſeveral ſimple machines or mechanical powers above-mentioned, the number of which in the preſent advanced ſtate of the ſciences is almoſt infinite. Theſe are again claſſed under different denominations, according to the agents by which they are put in motion, the purpoſes they are intended to effect, or the art in which they are employed, as hydraulic, pneumatic, military, architectural, &c. machines. The ancients excelled in the two latter ſpecies of engines, but in thoſe which relate to civil arts and manufactory, the moderns have doubtleſs far exceeded their maſters. With regard to military machines, the invention of gunpowder has completely changed their nature, and all thoſe of the ancients are become uſeleſs and forgotten; theſe were principally of three diſtinct ſpecies, *viz*. thoſe employed for throwing deſtructive weapons; as the *ſcorpion*, which was for caſting arrows; the *catapulta* for ſtones and javelins; the *pyrobole* for flaming darts; the *balliſta* for bullets, &c. &c.

Others were for razing the walls of fortified places, of which the principal was the *aries*, or *battering ram*; and thofe of the third kind were for covering the approaches of the befiegers, as the wooden tower, &c.; for a defcription of which fee the refpective articles. The warlike machines employed by Archimedes in the defence of Syracufe have been much applauded by the ancients, and though many of the circumftances related on this head are doubtlefs falfe or exaggerated, yet it is fufficient to know the genius of their author to be convinced that they were powerful and effective, probably much exceeding any of thofe of which the conftruction has been afcertained.

Of the architectural machines of the ancients we are totally unacquainted, and one is at a lofs to conceive what means they employed for tranfporting and raifing thofe enormous ftones which are found in the walls of fome ancient buildings, though it is not unlikely that they owed as much to their patient perfeverance and manual labour, as to the power of their machines. The Spaniards, when they made the conqueft of Peru, were ftruck with aftonifhment to find the natives, whom they confidered as favages and barbarians, raifing enormous maffes of ftone of ten feet fquare for building walls and other purpofes, without the affiftance of any inftruments than thofe which nature had fupplied them with: unacquainted with any other fcaffolding but that of banks of earth raifed againft their buildings, they contrived by ftrength of hand to raife thefe maffy loads up the inclined planes thus formed; and many of the Druidical remains in this country were probably erected in a fimilar manner. The ancient Greek and Roman architects, however, were no doubt acquainted with, and employed very powerful machines in the conftruction of their noble edifices, with the nature of which we have not been informed; even Vitruvius, who writes exprefsly on the fubject, has left us nothing that can throw any light on the conftruction of thefe engines, yet that they were in poffeffion of immenfe and wonderful machinery, appears in the moft convincing manner to any perfon who reflects on the magnificent ftructures which they erected, and which excite to this day the wonder and admiration of the world, not only on account of their grandeur and incomparable elegance, but alfo on account of the mechanical knowledge that feems indifpenfably neceffary for their erection.

The hydraulic machines of the ancients were indeed much inferior to thofe of modern invention. The *fcrew* of Archimedes, and the *pumps* of Ctefibius, were the principal engines of this defcription; for which fee the refpective articles. As to the modern machines they are too numerous to admit even of a flight enumeration in this place; moft of them, however, of any importance, will be found under the feveral heads in this work. See Cranes, *Wind* and *Water* Mills, Steam *Engine*, &c. &c.

Montucla, at the conclufion of the third volume of his "Hiftoire des Mathematiques," has given a catalogue of feveral interefting works, which have been compiled in order to defcribe and exhibit the moft important and curious machines, both ancient and modern, of which we have felected a few for the information of thofe who may not poffefs the above-mentioned work.

1. The firft and moft interefting modern work of this defcription is entitled "Le diverfe et artificiofe machine del capitano Agoftino Ramelli dal ponte della Trefia, &c. &c. compofte in lingua Italiana et Francefe; a Parigi 1588," in folio, (in Germany,) in 1620. This is a very fcarce work, feldom to be met with but in choice libraries.

2. "Machinæ novæ Faufti Verantii cum declaratione, Latina, Italica, Hifpanica, Gallica, et Germanica," Venetiis 1591, 1625, in folio, with figures.

3. "Récueil de plufieurs Machines militaires, &c. pour la Guerre et Récreations," par François Thypourel et Jean Appus, 1620, 4to.

4. "Heinrich Zeizings, Theatrum machinarum," Leipfic 1621.

5. "A Century of Inventions, &c." by Edward Somerfet, marquis of Worcefter, London 1663, in 12mo.

6. "Les dix Livres d'Architecture de Vitruve, &c." tranflated into French by Claude Perrault, 1673, folio.

7. "Veterum mathematicorum, Athenaci, Apollodori, &c." 1693, folio. This learned and curious edition of the ancient Greek machinicians was begun by Thevenot, and finifhed by La Hire; but it relates principally to military engines.

8. "Theatrum machinarum univerfale, &c." by Jacob Leupold, Leipfic, feven volumes folio, 1724, 1727, 1774. This is the greateft and moft complete work of the kind that ever was publifhed. The firft volume is little more than an introduction to the work; the fecond and third volumes contain defcriptions of hydraulic machines; the next two volumes relate to machines for raifing weights, the theory of levelling, and other fubjects; and the fixth treats principally on machines connected with the conftruction of bridges; the feventh volume is entitled "Théatre arithmetico geometrique," where the author treats of all inftruments employed in thefe two fciences. This work would have been much more confiderable, if its author had lived to complete the immenfe tafk he had undertaken.

9. "A fhort Account of the Methods made ufe of in laying of the Foundation of the Piers of Weftminfter Bridge," by Charles Labelye, 1739.

10. "The Advancement of Arts, Manufactures, and Commerce; or, A Defcription of ufeful Machines and Models," by A. M. Bailly, London 1778, 1779, folio.

Befides the above-mentioned works, many ufeful particulars may be gathered from Strada, Beffon, Beroaldus, Bockles, Beyer, Lempergh, Van Zyl, Belidor's Architecture hydraulique, Defaguliers's Courfe of experimental Philofophy, Emerfon's Mechanics. The Royal Academy of Sciences at Paris have alfo given a collection of machines and inventions approved of by them. This work, publifhed by M. Gallon, confifts of fix volumes in quarto, containing engraved reprefentations of the machines, with their defcriptions annexed.

We might have carried the enumeration of works of this kind to a much greater length, but the above are the moft interefting, and the reader who wifhes for farther information on this fubject may confult the hiftory of Montucla above-mentioned. But we ought not to omit to mention in this place, the fecond volume of the "Architecture Hydraulique" of Prony, and the fecond volume of Gregory's Mechanics: the firft of thefe relates principally to fteam engines, but the latter contains a defcription of the moft ufeful modern machines for various purpofes.

In the conftruction of machinery, as alfo in eftimating its effects, feveral important confiderations naturally arife in the mind of a fkilful artift, fuch as the effect of Friction, Rigidity of *ropes*, the Strength and Stress of materials; the proper meafure, comparifon, and equilibrium of Forces, the laws of Rotatory and Accelerated *motion*, &c. &c. Thefe are all treated of under the refpective articles in the Cyclopædia, and it therefore only remains for us in this place to offer a few remarks on the nature of machines in general, and the beft means of determining their maximum effects.

Machines are introduced for three purpofes, viz. to ac-

commodate the direction of the moving force to that of the resistance to be overcome: to increase the effect of a given finite power, so as to overcome a resistance which is greater, and would otherwise ever remain unchanged: and lastly, to regulate and modify a variable force, so as to produce a constant and uniform effect. These are the principal ends to be accomplished by machines, and the experienced engineer will always endeavour to execute them in the simplest manner possible; for complicated machinery is not only most liable to inaccurate adjustment, and frequent disarrangement, but is likewise more cumbersome and expensive, at the same time that the retardation arising from friction, adhesion, and inertia, is more considerable, and consequently a greater power becomes necessary, in order to produce the same effect. Another important point to be attended to, is the most advantageous application of the first mover, whether this agent be air, water, steam, or animal strength. To enter upon this question in all its generality, would far exceed our limits; besides, with regard to the three former, they will be better investigated under the articles *Wind* and *Water* MILLS, STEAM *Engine*, &c.; what few remarks, therefore, we have to make on this head, will be confined to the application of animal exertion to the motion of machines, and for the other agents we must refer the reader to the articles above-mentioned.

We have a striking instance of the injudicious application of the exertion of men, in the old crane worked by means of an internal walking wheel, which, from its nature, must be very heavy, while the action of the man is exerted at a very trifling distance from the axle, and consequently at a great mechanical disadvantage; whereas in Hardie's crane, the man acting externally at the greatest distance from the fulcrum, produces a much greater effect with less expence of labour; the other advantages which this machine possesses over the one above-mentioned, not arising solely from this cause, are not connected with our present enquiry.

The above remark applies principally to the mechanical advantage to be obtained in the application of a first mover; but there is also another consideration of a physical nature, which is equally important, and ought therefore to be particularly attended to. No animal can exert more than a determinate and limited force; and, consequently, if it requires all this force merely to produce an equilibrium, no effect will result from the action; and, on the other hand, if all the strength of a man or horse is employed in giving motion to himself, or to external objects before the application reaches the resistance, there is still the same unproductive effect. A man, for example, pushing at a capstan bar, must first of all walk as fast as the bar moves round, which evidently requires an expenditure of his muscular power; but this alone will not render his exertion effective: he must also press the bar forward, with as much force as he has remaining above that which he expended in walking at that rate. The proportion of these two expenditures may be very different under different circumstances; and on the judicious selection of such circumstances as make the first of these as small as possible, lies much of the skill of the engineer. In the common operation of thrashing corn, much more than half the man's power is expended in giving the necessary motion to his own body; and only the remainder is employed in urging forward the swiple with a momentum sufficient for shaking out the ripe grains from the stalk. Dr. Robison mentions an experiment, made in order to ascertain the quantity of power thus lost. In order to which, the swiple was taken off the flail, and the same weight of lead put on the end of the staff; then by causing the labourer to perform the usual motions of thrashing, with all the rapidity that he could continue during the ordinary hours of work; it was found that the number of motions thus made was to those made in the actual operation of thrashing, in about the ratio of 3 to 2: whence we may infer, that at least half the thrasher's power is expended in merely moving his own body. We may also bring another very simple case, by way of further illustration. Suppose a quantity of earth is to be removed from one place to another by barrows. It is obvious that the loads may be so great, that a man must exert his whole strength barely to lift up the shafts, and consequently will have none left to push the barrow forward: if part of the load be taken off, he can go forward, and so much the faster as the quantity of the load is reduced; but if even the whole be taken away, he can still only move at a certain rate, and, consequently, in neither of the extreme cases is any effect produced. It becomes then an interesting question to determine what load he ought to carry, in order to produce the greatest possible effect in a given time. We shall not, in this place, enter any farther upon this subject, trusting that what has been already advanced will be sufficient to point out the necessity of attending to such circumstances; and in the subsequent part of the present article, we will endeavour to explain in what manner the proper adjustment of power and effect may be computed.

The nature of the first movement being determined, the next object is to communicate it to the destined point, where the resistance is to be overcome; and much of an artist's skill depends upon performing this in the simplest and most effectual manner possible. In order to this, it frequently becomes necessary to convert one species of motion into another species: as, for example, a rotatory into a reciprocating motion, or a reciprocating into a rotatory motion, &c. &c. The methods of forming this communication are extremely numerous, and it will not therefore be expected that we should attempt an enumeration of them. In some instances, a simple lever or unbent cord will answer better than any combination; in others, it is highly advantageous to use a combination of levers acting upon each other by means of so many fulcra, and by which the direction of the motion may be changed at pleasure; in others, as when motion is communicated to a series of wheels and axles in succession, it may be effected by a rope running in grooves round one wheel and the succeeding axle, or by means of tooth and pinion work, by a barrel and endless screw, and various other contrivances which will naturally suggest themselves, according to the circumstances under which they arise.

This part of the construction being settled, other important circumstances require particular attention, *viz.* to adjust the several parts of the machine so, that its motion may be easy, free, and uniform. One of the most obvious methods of rendering a motion uniform is by means of a *pendulum* and *scapement* (see these two articles); and where these cannot conveniently apply, a fly is sometimes employed; for a particular description of which, see FLY. The uniformity of a machine is not, however, wholly dependent upon the application of such regulators: there are other points connected with this subject, that must not be overlooked, and on which we intend to offer a few remarks; availing ourselves, for this purpose, of the observations of Dr. Robison. When heavy stampers are to be raised, in order to drop on the matters to be pounded, the wipers by which they are lifted should be made of such a form, that the stamper may be raised by a uniform pressure, or with a motion almost perfectly uniform: if this is not attended to, and the wiper is merely a pin sticking out from the axis, the stamper is forced into action at once, which occasions violent

jolts to the machine, and great ſtrains on its moving parts, and their points of ſupport; whereas, when they are gradually lifted, the inequality of the motion is never felt at that point of the machine where the power is applied. We have ſeen, ſays the profeſſor, piſtons moved by means of a double rack on the piſton rod, where a half wheel takes hold of one rack, and raiſes it to the required height; and the moment the half wheel has quitted that ſide of the rack, it lays hold of the other ſide, and forces the piſton down again. This was conſidered as an improvement of the common method of the crank, by correcting the unequable motion of the piſton. But in fact it is far inferior to the latter, as it occaſions ſuch abrupt changes of motion, that the machine is ſhaken and torn to pieces with the jolts it occaſions; a circumſtance which will always be avoided as much as poſſible by a judicious engineer.

When ſeveral ſtampers, piſtons, or other reciprocal movers, are to be raiſed and depreſſed, their times of action ought to be diſtributed in a uniform manner, ſo that the machine may always be equally loaded with work. When this is done, and the obſervations in the preceding paragraph attended to, the machine may be made to move almoſt as ſmoothly as if there were no reciprocations on it. Nothing ſhews the ingenuity of the conſtructor more than the artful, yet ſimple, contrivances for obviating thoſe difficulties that unavoidably ariſe from the very nature of the work that muſt be performed by the machine, and of the power employed. We mentioned, above, the converſion of the continued rotation of an axis into the reciprocating motion of a piſton, and the improvement that was thought to have been made in the common and obvious contrivance of the crank, but which, as was obſerved, occaſioned ſuch jolts as would in a ſhort time have deſtroyed the machine. In order to avoid this, in a large forge where a great ſledge hammer of ſeven hundred weight was to be raiſed, the engineer formed the wipers into ſpirals, which communicated motion to the hammer almoſt without any jolt whatever: and under ſome circumſtances, this contrivance would have been highly beneficial; but in the machine to which we allude, it would not apply, as it did not communicate a ſufficient momentum to the hammer in its deſcent: yet it is deſerving of notice, as it might in ſome caſes become extremely advantageous.

In employing a power, which of neceſſity reciprocates, to drive machinery, in which a rotatory motion is required, as in applying the ſteam-engine to a cotton or griſt-mill, conſiderable difficulties alſo ariſe, which muſt be attended to with particular care. The neceſſity of reciprocation on the firſt mover waſtes much power, becauſe the inſtrument that communicates ſuch immenſe force muſt be extremely ſtrong, and well ſupported. The impelling power is waſted in imparting, and afterwards deſtroying, a great quantity of motion in the working beam. The ſkilful engineer will attend to this, and do his utmoſt to procure the neceſſary ſtrength of the firſt mover, without making it a vaſt load of inert matter: he will alſo remark that all the ſtrains on it, and on its ſupports, are changing their direction on every ſtroke; which therefore requires particular attention in the manner of ſupporting it. If we obſerve ſteam-engines that have been long erected, we ſhall find that they have uniformly ſhaken the building to pieces, which is principally to be attributed to the inattention of the engineer to this circumſtance; and experience has now taught us, that no building can long withſtand the deſultory and oppoſite jolts of ſuch immenſe maſſes; and, conſequently, that the great movements ought to be ſupported by a frame-work, independent of the building which contains it. Another circumſtance, on which the uniformity of the motion depends, is the form given to the teeth of the wheel: this is of great importance, and has excited great attention amongſt both theoretical and practical machinicians. Two forms have been propoſed: of theſe the firſt was given by La Hire, who affirmed that the preſſure would be uniform, if the teeth were formed into epicycloids; and M. Camus, in his "Cours de Mathematique," has adopted and purſued La Hire's principle, and applied it to the various caſes that are likely to ariſe in practice. This conſtruction, however, is liable to a limitation; on which account, a ſecond method has been propoſed, which ſecures the perfect uniformity of motion, without any ſuch limitation. This conſiſts of making both teeth portions of involutes of circles; but as we ſhall conſider this ſubject under the articles TOOTH and PINION *Work*, it will be uſeleſs to inſiſt any farther upon it in this place; and we will therefore proceed to the theoretical inveſtigation of the power of machines, and their maximum effects; limiting our obſervation to thoſe principally whoſe motion is uniform, theſe forming by far the moſt numerous claſs, and the knowledge of which is, therefore, of the greateſt importance.

Of the maximum Effects of Machines.—When forces acting in contrary directions, or in any ſuch directions as produce contrary effects, there is with reſpect to every ſimple machine, and conſequently with reſpect to every compound one, a certain relation between the powers and the diſtances at which they act, which, if ſubſiſting in any ſuch machine when at reſt, will preſerve it in that ſtate of ſtatical equilibrium; becauſe the efforts of theſe powers, when thus related with regard to magnitude and diſtance, being equal and oppoſite, deſtroy each other, and have no tendency to change the ſtate of the ſyſtem to which they are applied. So alſo, if the ſame machine have been put into a ſtate of uniform motion, whether rectilinear or rotatory, by the action of any power diſtinct from thoſe we are now conſidering, and theſe two powers be made to act upon the machine in ſuch motion, in a ſimilar manner to that in which they act upon it when at reſt, their ſimultaneous action will preſerve it in that ſtate of uniform motion, or dynamical equilibrium, and this for the ſame reaſon as before; becauſe their contrary effects deſtroy each other, and have, therefore, no tendency to change the ſtate of the machine. But if at the time a machine is in a ſtate of balanced reſt, any one of the oppoſite forces be increaſed, while it continues to act at the ſame diſtance, this exceſs of force will diſturb the ſtatical equilibrium, and produce motion in the machine; and if the ſame exceſs of force continues to act in the ſame manner, it will, like every conſtant force, produce an accelerated motion; or if it ſhould undergo particular modifications, when the machine is in different poſitions, it may occaſion ſuch variations as will render it alternately accelerated and retarded. Or, the different ſpecies of reſiſtance to which a moving machine is ſubjected, as the rigidity of cords, friction, reſiſtance of the air, &c. may ſo modify it, as to change a regular or irregular variable motion into one which is uniform. Hence, then, the motion of machines may be conſidered as of three kinds, as that which is gradually accelerated, which obtains commonly in the firſt inſtants of the communication. 2. That which is entirely uniform. 3. That which is alternately accelerated and retarded. Pendulum clocks and machines that are moved by a balance are related to the third claſs. Moſt other machines are of the ſecond claſs, at leaſt a ſhort time after their motion is commenced.

Now, although the motion of a machine be alternately accelerated and retarded, it may, notwithſtanding, be mea-

ſured by an uniform motion, in conſequence of the periodical and regular repetition which may exiſt in the acceleration and retardation. Thus, the motion of a ſecond pendulum, conſidered in relation to a ſingle oſcillation, is accelerated during the firſt half ſecond, and retarded during the ſecond; but the ſame motion taken for many oſcillations may be conſidered as uniform. Suppoſe, for example, that the extent of each oſcillation is five inches, and that the pendulum has made ten oſcillations; its total effect will be to have run over 50 inches in 10 ſeconds, and as the ſpace deſcribed in each ſecond is the ſame, we may compare the effects to a moveable, which moves for 10 ſeconds at the rate of five inches *per* ſecond. We ſee, therefore, that the theory of machines, whoſe motions are uniform, conduces naturally to the eſtimation of the effects of thoſe whoſe motion is alternately accelerated and retarded, ſo that what follows will be directed to thoſe machines only, whoſe motion falls under the ſecond head, ſuch problems being of far the greateſt utility in practice.

We have had already frequent occaſion to make uſe of the terms *mover*, or *moving force* and *reſiſtance*; and in what follows, they will be uſed in the ſame general ſenſe. By the firſt is always to be underſtood any cauſe of motion whatever, and by the latter, any thing that is oppoſed to the action of the former. The *impelled point* of a machine, is that to which the action of the moving power may be conſidered as immediately applied; and the *working point* is that where the reſiſtance ariſing from the work to be performed immediately acts, or to which it ought all to be reduced. Thus in the wheel and axle, *Plate* I. *fig.* 6. *Mechanics*, where the moving power P is to overcome the weight or reſiſtance W, by the application of the cord to the wheel and to the axle, A is the impelled point, and E the working point. The *velocity of the moving power* is the ſame as the velocity of the impelled point; and the *velocity of the reſiſtance*, the ſame as that of the working point. The *performance* or *effect* of a machine, or the *work done*, is meaſured by the product of the reſiſtance into the velocity of the working point; and the *momentum of impulſe* is meaſured by the product of the moving force into the velocity of the impelled point.

Theſe definitions being eſtabliſhed, we may exhibit a few of the moſt uſeful problems relative to the effect of machines, and with which we muſt conclude this article.

Let A B (*Plate* XXXII. *Mechanics*, *fig.* 1.) repreſent the velocity of a ſtream, A C the velocity of the part of the engine which it ſtrikes, when the motion of the machine becomes uniform, and C B will repreſent their relative velocity, upon which the effect of the engine depends. It is known that the action of a fluid upon a given plane, is as the ſquare of this relative velocity; conſequently the weight raiſed by the engine, when its motion becomes uniform, being equal to this action, it is likewiſe as the ſquare of C B. Let this be multiplied by A C, the velocity of the part of the engine, impelled by the fluid; and the effect of the engine in a given time will be proportional to $AC \times CB^2 =$ (ſuppoſing C B to be biſected in D) $AC \times 2CD \times 2DB = 4AC \times CD \times DB$; conſequently, the effect of the engine is greateſt when the product of A C, C D, and D B is greateſt. But it is eaſy to ſee, that this product is greateſt when the parts A C, C D, and D B, are equal; for if you deſcribe a ſemicircle upon A D, and the perpendicular C E meet the circle in E, then $AC \times CD = CE^2$, and is greateſt when C is the centre of the circle; ſo that in order that $AD \times CD \times DB$ may be the greateſt poſſible, A D muſt be biſected in C; and C B having been biſected in D, it follows that A C, C D, D B, muſt be equal; or that A C, the velocity of the part of the engine impelled by the ſtream, ought to be but one-third of A B, the velocity of the ſtream. In this caſe, when, (abſtracting from friction) the engine acts with the utmoſt advantage; the weight raiſed by it is to the weight that would juſt ſuſtain the force of the ſtream, as the ſquare of C B, the relative velocity of the engine and ſtream, to the ſquare of A B, which would be the relative velocity, if the engine was quieſcent; that is, as 2×2 to 3×3, or 4 to 9. Therefore, that the engine may have the greateſt effect poſſible, it ought to be loaded with no more than $\frac{4}{9}$ths of the weight, which is juſt able to ſuſtain the efforts of the ſtream. See Maclaurin's Account of ſir Iſaac Newton's Diſcoveries, p. 171, and Fluxions, art. 908.

Again, ſuppoſe that a given weight P, (*fig.* 2.) deſcending by its gravity in the vertical line, raiſes a greater weight W, likewiſe given, by the rope P M W, (that paſſes over the fixed pulley M) along the inclined plane B D, the height of which B A is given; and let it be required to find the poſition of this plane, along which W will be raiſed in the leaſt time, from the horizontal line A D to B. Let B C be the plane upon which, if W was placed, it would be exactly ſuſtained by P; in which caſe, P is to W as A B to B C. But W is to the force with which it tends to deſcend along the plane B D, as B D to A B; conſequently the weight P is to that force, as B D to B C. Therefore the exceſs of P above that force (which exceſs is the power that accelerates the motion of P and W) is to P, as $BD - BC$ to B D; or taking B H upon B C equal to B D, as C H to B D. But it is known that the ſpaces deſcribed by motions uniformly accelerated, are in the compound ratio of the forces which produce them and the ſquares of the times; or, that the ſquare of the time is directly as the ſpace deſcribed in that time, and inverſely as the force; conſequently, the ſquare of the time in which B D is deſcribed by W, will be directly as B D, and inverſely as $\frac{CH}{BD}$, and will be leaſt when $\frac{BD^2}{CH}$ is a minimum; that is, when $\frac{BC^2}{CH} + CH + 2BC$, or (becauſe 2 B C is invariable) when $\frac{BC^2}{CH} + CH$, is a minimum. Now as when the ſum of two quantities is given, their product is a maximum when they are equal to each other; ſo it is manifeſt, that, when their product is given, their ſum muſt be a minimum when they are equal. Thus it is evident, that as in *fig.* 1, the rectangle or product of the equal parts A C and C D was equal to CE^2; ſo the rectangle of any two unequal parts, into which A D may be divided, is leſs than CE^2, and A D is the leaſt ſum of any two quantities, the product of which is equal to CE^2. But the product of $\frac{BC^2}{CH}$ and C H is BC^2, and conſequently given: therefore the ſum of $\frac{BC^2}{CH}$ and C H is leaſt when theſe parts are equal, that is, when C H is equal to B C, or B D equal to 2 B C. It appears, therefore, that when the power P and weight W are given, and W is to be raiſed by an inclined plane, from the level of a given point A to the given point B in the leaſt time poſſible; we are firſt to find the plane B C, upon which W would be ſuſtained by P, and to take the plane B D double in length of the plane B C; or we are to make uſe of the plane B D, upon which

a weight that is double of W could be fustained by the power P.

For another example; fuppofe a fluid, moving with the velocity and direction A C, (*fig.* 3.) ftrike the plane C E; and fuppofe that this plane moves parallel to itfelf in the direction C B, perpendicular to C A, or that it cannot move in any other direction. Then let it be required to find the moft advantageous pofition of the plane C E, that it may receive the greateft impulfe from the action of the fluid. Let A P be perpendicular to C E in P, draw A K parallel to C B, and let P K be perpendicular upon it in K, and A K will meafure the force with which any particle of the fluid impels the plane E C, in the direction C B. For the force of any fuch particle being reprefented by A C, let this force be refolved into A Q, parallel to E C, and A P perpendicular to it; and it is manifeft, that the latter A P only has any effect upon the plane C E. Let this force A P be refolved into the force A L perpendicular to C B, and the force A K parallel to it; then it is manifeft, that the former, A L, has no effect in promoting the motion of the plane in the direction C B; fo that the latter A K, only, meafures the effort by which the particle promotes the motion of the plane C E in the direction C B. Let E M and E N be perpendicular to C A and C B, in M and N; and the number of particles, moving with directions parallel to A C, incident upon the plane C E, will be as E M. Therefore the effort of the fluid upon C E being as the force of each particle, and the number of particles together, it will be as A K $\times$ E M; or, becaufe A K is to A P (= E M) as E N to C E, as $\frac{ME^2 \times EN}{CE}$; fo that C E being given, the problem is reduced to this, to find when E M^2 $\times$ E N is the greateft poffible, or a maximum. But becaufe the fum of E M^2 and of E N^2 (= C M^2) is given, being always equal to C E^2, it follows that E N^2 $\times$ E M^4 is greateft when E N^2 = $\frac{1}{3}$ C E^2; in the fame manner as it was demonftrated above, that when the fum of A C and C B (*fig.* 1.) was given, A C $\times$ C B^2 was greateft, when A C = $\frac{1}{3}$ A B. But when E N^2 $\times$ E M^4 is greateft, its fquare root E N $\times$ E M^2 is of neceffity at the fame time greateft. Therefore the action of the fluid upon the plane C E, in the direction C B, is greateft when E N^2 = $\frac{1}{3}$ C E^2, and confequently E M = $\frac{2}{3}$ C E^2; that is, when E M, the fine of the angle A C E, in which the ftream ftrikes the plane, is to the radius, as the $\surd$ 2 to $\surd$ 3; in which cafe it eafily appears, from the trigonometrical tables, that this angle is of 54° 44′.

Several ufeful problems in mechanics may be refolved by what was fhewn in the preceding paragraph. If we reprefent the velocity of the wind by A C, a fection of the fail of a windmill, perpendicular to its length by C E, as it follows from the nature of the engine, that its axis ought to be turned directly towards the wind, and the fail can only move in a direction perpendicular to the axis, it appears, that when the motion begins, the wind will have the greateft effect to produce this motion, when the angle A C E, in which the wind ftrikes the fail, is of 54° 44′. In the fame manner, if C B reprefent the direction of the motion of a fhip, or the pofition of her keel, abftracting from her lee-way, and A C be the direction of the wind, perpendicular to her way, then the moft advantageous pofition of the fail C E, to promote her motion in the direction C B, is when the angle A C E, in which the wind ftrikes the fail, is of 54° 44′. The beft pofition of the rudder, where it may have the greateft effect in turning round the fhip, is determined in like manner, and the fame angle enters likewife into the determination of the figure of the rhombufes that form the bafes of the cells in which the bees depofit their honey in the moft frugal manner. (See HONEY-*Comb.*) But it is to be carefully obferved, that when the fine of the angle A C E is to the radius as $\surd$ 2 to $\surd$ 3; or, which is the fame thing, when its tangent is to the radius as the diagonal of a fquare to its fide; this is the moft advantageous angle only at the beginning of the motion of the engine; fo that the fails of a common windmill ought to be fo fituated, that the wind may indeed ftrike them in a greater angle than that of 54° 44′. For it is demonftrable, that when any part of the engine has acquired the velocity c, the effort of the wind upon that part will be greateft, when the tangent of the angle in which the wind ftrikes it, is to the radius, not as the $\surd$ 2 to 1, but $\surd 2 \times \frac{9c^2}{4a^2} \times \frac{3c}{2a}$ to 1, the velocity of the wind being reprefented by a. If, for example, $c = \frac{1}{2} a$; then the tangent of the angle A C E ought to be double of the radius; that is, the angle A C E ought to be of 63° 26′. If $c = a$; then A C E ought to be of 74° 19′. This obfervation is of the more importance, becaufe, in this engine, the velocity of the parts of the fail remote from the axis bears a confiderable proportion to the velocity of the wind, and perhaps fometimes is equal to it; and becaufe a learned author, Daniel Bernouilli, has drawn an oppofite conclufion from his computations in his hydrodynamics, by miftaking a minimum for a maximum; where he infers, that the angle in which the wind ftrikes the fail, ought to decreafe as the diftance from the axis of motion increafes; that if $c = a$, the wind ought to ftrike in an angle of 45°; and that if the fail be in one plane, it ought to be inclined to the wind, at a medium, in an angle of 50°. How he fell into thefe miftakes, is fhewn by Maclaurin, in his Fluxions, § 914.

In like manner, though the angle A C E of 54° 44′ be the moft advantageous at the beginning of the motion, when a fhip fails with a fide wind; yet it ought to be enlarged afterwards as the motion increafes. In general, let A a (*fig.* 3) parallel to C B, be to A C, as the velocity which the engine has already acquired in the direction C B, to that of the ftream; upon A C produced, take A D to A C as 4 to 3, draw D G parallel to C B, and let a circle defcribed from the centre C with the radius C a, meet D G in g; and the plane C E fhall be in the moft advantageous fituation for promoting the motion of the engine, when it bifects the angle a C g.

It is generally fuppofed, that a direct wind always promotes the motion of a fhip, the fail being perpendicular to the wind, more than any fide-wind; and this has been affirmed in feveral late ingenious treatifes; but, to prevent miftakes, we are obliged to obferve, that Maclaurin has demonftrated the contrary in his Treatife of Fluxions, § 919; where other inftances of this fecond general problem in mechanics are given, to which we refer. See Maclaurin's Account of fir Ifaac Newton's Philofophical Difcoveries, book ii. chap. 3. p. 173.

Let φ denote the abfolute effort of any moving force, when it has no velocity, and fuppofe it not capable of any effort when the velocity is W; let F be the effort anfwering to the velocity V, then if the force be uniform, we fhall have

$$= \varphi \left(1 - \frac{V}{W}\right)$$

For it is the difference between the velocities W and V which is efficient, and the action, being constant, will vary as the square of the efficient velocity. Hence we shall have this analogy,

$$\varphi : F :: (W - 0)^2 : (W - V)^2,$$

and, consequently,

$$F = \varphi \left(\frac{W - V}{W}\right)^2 = \varphi \left(1 - \frac{V}{W}\right)^2 \quad \text{Q.E.D.}$$

Although the pressure of an animal is not actually uniform during the whole time of its action, yet it is nearly so, and therefore in general we may adopt this hypothesis, in order to approximate to the true nature of animal action. On which supposition the preceding proposition, as well as the following one, will apply to animal exertion. By retaining the same notation, we have also

$$W = \frac{V \sqrt{\varphi}}{\sqrt{\varphi} - \sqrt{F}},$$

which formula, applied to the motion of animals, gives the following theorem.

The utmost velocity with which an animal, unimpeded, can move, is to the velocity with which it moves when impeded with a given resistance; as the square root of its absolute force to the difference of the square roots of its absolute and efficient forces.

Again, to investigate expressions by means of which the maximum effect, in machines whose motion is uniform, may be determined.

1. It follows from the observations made in the preceding part of this article, that when a machine, whether simple or compound, is put into motion, the velocities of the impelled and working points are inversely as the forces which are in equilibrio when applied to those points in the direction of their motion. Consequently, if f denotes the resistance when reduced to the working point, and v its velocity; while F denotes the force acting at the impelled point, and V its velocity, we shall have $F V = f v$, or introducing t, the time, $F V t = f v t$. Hence

In all working machines which have acquired an uniform motion, the performance of the machine is equal to the momentum of the impulse.

2. Let F be the effort of a force upon the impelled point of a machine, when it moves with a velocity V, the velocity being W, when $F = 0$, and let the relative velocity $W - V = u$.

Then, since $F = \varphi \left(\frac{W - V}{W}\right)^2$, by the foregoing proposition, the momentum of impulse F V becomes

$$F V = V \varphi \left(\frac{u}{W}\right)^2 = \varphi \frac{u^2}{W^2} (W - u);$$

because, since $W - V = u$, we have $V = W - u$.

Now making this expression for F V a maximum, or suppressing the constant quantities, and making

$$u^2 (W - u) = \text{a maximum},$$

we have, by throwing it into fluxions,

$$2 u \dot{u} W - 3 u^2 \dot{u} = 0, \text{ or } 2 W = 3 u, \text{ or } u = \tfrac{2}{3} W:$$

whence, again, $V = W - u = W - \frac{2}{3} W = \frac{1}{3} W$.

Consequently, when the ratio of V to v is given by the construction of the machine; and the resistance is susceptible of variation, we ought to load the machine more or less, till the velocity of the impelled point is one-third of the greatest velocity of the force, in order that the work done may be a maximum.

Or the work done by an animal is the greatest when the velocity with which it moves, is one-third of the greatest velocity with which it is capable of moving when not impeded.

Again, since we have

$$F = \varphi \frac{u^2}{W^2} = \varphi \frac{\frac{4}{9} W^2}{W^2} = \tfrac{4}{9} \varphi,$$

in the case of the maximum, we have also

$$F V = \tfrac{4}{9} \varphi V = \tfrac{4}{9} \varphi \cdot \tfrac{1}{3} W = \tfrac{4}{27} \varphi W,$$

for the momentum of impulse, or for the work done when the machine is in the best state.

Consequently, when the resistance is a given quantity, we must make

$$V : v :: 9 f : 4 \varphi,$$

which structure of the machine will give the maximum effect $= \frac{4}{27} \varphi W$.

If we enquire the greatest effect on the supposition that φ only is variable, we must make it infinite in the above expression for the work done, which would then become

$$W F, \text{ or } W \frac{V}{v} f, \text{ or } W \frac{V}{v} f t,$$

including the time in the formula.

Whence we come to this important conclusion, *viz.*

That the sum of the agents employed to move a machine may be infinite, while the effect is finite.

For the variations of φ, which are proportional to this sum, do not influence the above expression for the effect. The last theorem may be applied to the action of men and of horses, with more accuracy than might at first be supposed. Observations have been made on men and horses drawing a lighter along a canal, and working several days together. The force exerted was measured by the curvature and weight of the track rope, and afterwards by a spring steel-yard. The product of the force thus ascertained into the velocity *per* hour, was considered as the momentum; and in this way the action of the men was found to be very nearly as $(W - V)^2$. The action of the horses, loaded so as not to be able to trot, was nearly as $(W - V)^{\cdot 6}$, or as $(W - V)^{\frac{2}{3}}$. Hence the hypothesis above adopted may, in many cases, be safely assumed. According to the best observations, the force of a man at rest is on an average about seventy pounds, and the utmost velocity with which he can walk is about six feet *per* second, taken at a medium. Hence in the above theorems $\varphi = 70$, and $W = 6$; consequently $F = \frac{4}{9} \varphi = 31\frac{1}{9}$lbs., the greatest force a man can exert when in motion, and he will then move at the rate of $\frac{1}{3}$ W, or two feet *per* second, or rather less than $1\frac{1}{2}$ mile *per* hour.

The strength of a horse is generally reckoned about six times that of a man, that is, about 420lbs. at a dead pull. His utmost walking velocity is about ten feet *per* second; and therefore his maximum action will be $\frac{4}{9} \times 420 = 186\frac{2}{3}$lbs. and he will then move at the rate of $\frac{1}{3}$ of 10, or $3\frac{1}{3}$ feet *per* second, or nearly $2\frac{1}{4}$ miles *per* hour. In both these instances we suppose the force to be exerted in drawing a weight, by a cord running over a pulley, which makes its direction horizontal.

The theorem above given may serve to shew under what points of view machines ought to be considered by those who would labour beneficially for their improvement. The first object of utility is in furnishing the means of giving

to the moving force the most commodious direction, and when it can be done of causing its action to be applied immediately to the body to be moved. These, it is true, can rarely be united, but the former may, in most instances, be accomplished; of which the use of the simple lever, pulley and wheel and axle, furnish many examples. The second object gained by the use of machines, is an accommodation of the velocity of the work to be performed, to the velocity with which alone a natural power can act. Thus, whenever the working power acts with a certain velocity, which cannot be changed, and the work must be performed with a greater velocity, a machine is interposed round a fixed support, and the distance of the impelled and working points are taken in the proportion of the two given velocities. But the essential advantage of machines, and that in fact which properly appertains to the theory of mechanics, consists in augmenting, or rather modifying the energy of the moving power, in such a manner that it may produce effects, of which it would otherwise have been incapable. Thus a man might carry up a flight of steps twenty pieces of stone, each weighing say 30lbs. one by one, in as small a time as he could, with the same labour, raise them all together with a piece of machinery, that would have the velocities of the impelled and working points as twenty to one, and in this case the instrument would furnish no real advantage except in saving his steps. But if a large block of 20 times 30, or 600lbs, were to be raised to the same height, it would far exceed his utmost efforts to accomplish it, without the intervention of some machine. Or the same purpose may be illustrated somewhat differently, confining the attention still to those machines whose motion is uniform. The product $f\,v$ represents, during the unit of time, the effect which results from the motion of the resistance; this motion being produced in any manner whatever. If it be produced by applying the moving force immediately to the resistance, it is necessary, not only that the product $F\,V = f\,v$, but also at the same time $F = f$ and $V = v$; if, therefore, as most frequently happens, f be greater than F, it will be absolutely impossible to put the resistance in motion, by applying the moving power immediately to it. Now, machines furnish the means of disposing of the product $F\,V$ in such a manner, that it may always be equal to $f\,v$, however much the factors $F\,V$ may differ from the analogous factors in $f\,v$; and consequently of putting the system in motion, whatever may be the excess of f above F. Or, generally, as Prony remarks, (Arch. Hydraul. art. 501.) machines enable us to dispose of the factors $F\,V\,t$ in such a manner, that while that product continues the same, its factors may have to each other any ratio at pleasure. Thus, to give another example: suppose that a man, exerting his strength immediately upon a mass of 25lbs. can raise it vertically, with the velocity of four feet *per* second; the same man acting upon a mass of 1000lbs. cannot give it any vertical motion, though he exerts his utmost strength, unless he has recourse to some machine. Now he is capable of producing an effect equal to $25 \times 4 \times t$; the letter t being introduced, because, if the labour be continued, the value of t will not be indefinite, but comprised within assignable limits. Thus we have $25 \times 4 \times t = 1000 \times v \times t$; and, consequently, $v = \frac{1}{10}$th of a foot. This man may, therefore, with a machine as a lever, or axis in *peritrochio*, cause a mass of 1000lbs. to rise $\frac{1}{10}$th of a foot in the same time that he could raise 25lbs. 4 feet without a machine; or he may raise the greater weight as far as the less, by employing forty times as much time. From what has now been said on the extent of the effects which may be attained by machines, it will be seen, that so long as a moving force exercises a determinate effort with a velocity likewise determinate, or so long as the product of these is constant, the effects of the machine will remain the same: so that under this point of view, supposing the preponderance of the effort of the moving power, and abstracting from inertia and friction of materials, the convenience of application, &c., all machines are equally perfect. But from what has been shewn in the preceding part of this article, a moving force may, by diminishing its velocity, augment its effort, and reciprocally. There is, therefore, a certain effort of the moving force, such that its product by the velocity, which comports to that effort, is the greatest possible. Now admitting of the truth of the results in the preceding propositions $V = \frac{1}{3} W$, or $F = \frac{4}{9} \varphi$, and these two values obtaining together their product, $\frac{4}{27} \varphi\,W$ expresses the value of the greatest effect with respect to the unit of time; and in practice it will always be advisable to approach as nearly to these values as circumstances will admit, for it cannot be expected that it can always be exactly attained. But a small variation will not be of much consequence; for by a well known property of those quantities, which admit of a proper maximum or minimum, a value assumed at a moderate distance from either of these extremes, will produce no sensible change in the effect.

If the relation of F to V followed any other law than that which we have assumed, we should find from the expression of that law, values of F and V, &c. different from the preceding, but the general method would be still nearly the same.

With respect to practice, the grand object in all cases should be to procure an uniform motion, because it is from that which, *ceteris paribus*, the greatest effect, always results. Every irregularity in the motion wastes some of the impelling power, and it is the greatest only of the varying velocities which is equal to that, which it would acquire if it moved uniformly throughout; for while the motion accelerates, the impelling power is greater than what balances the resistance at that time opposed to it, and the velocity is less than what the machine would acquire, if moving uniformly; and when the machine attains its greatest velocity, it attains it because the power is not then acting against the whole resistance. In both these cases, therefore, the performance of the machine is less than if the power and the resistance were exactly balanced, in which case it would move uniformly. Besides this, when the motion of a machine, and particularly a very ponderous one, is irregular, there are, as we have already remarked in the preceding part of this article, continual repetitions of strains and jolts, which soon derange, and ultimately destroy the whole structure.

In the preceding remarks and propositions, relative to the maximum effect of machines, we have availed ourselves of an interesting chapter on this subject in Gregory's Mechanics, in which the theory is pursued to a much greater length than our limits will admit of, both with regard to machines whose motions are uniform and accelerated; and to which we would refer the reader for further information. See also Prony's "Architecture Hydraulique," from art. 487 to 507; and the last edition of Ferguson's Mechanics by Brewster, in which an interesting paper on this subject is given by professor Leslie.

MACHINE for taking down extemporaneous pieces of music, commonly called *voluntaries*. Such a contrivance has been long among musical *desiderata* of the most important kind. To fix such floating sounds as are generated in the extatic moments of enthusiasm, while "bright-eyed fancy

"Scatters from her pictured urn,
Thoughts that breathe, and *notes* that burn,"

would be giving permanence to ideas which reflection can never find, nor memory retain.

The first idea of such a contrivance being practicable was suggested to the Royal Society of London, in a paper written by the late Rev. Mr. Creed, and sent to the president, 1747, under the following title:

"A demonstration of the possibility of making a *machine* that shall write *extempore voluntaries*, or other pieces of music, as fast as any master shall be able to play them, upon an organ, harpsichord, &c. and that in a character more natural and intelligible, and more expressive of all the varieties those instruments are capable of exhibiting, than the character now in use."

This paper was published the same year in the Philosophical Transactions, N° 183, and, afterwards, in Martyn's Abridgment, vol. x. p. 266; and the author's idea always appeared to us so feasible, that we have long wondered at its not having been executed by some ingenious English mechanic.

The first mention that we can find to have been made at Berlin, of such a contrivance, was in 1752, in a printed "Weekly Account of the most remarkable Discoveries in Nature and Science." In 1753, an ample description of such a machine appeared in the same weekly publication: and here, in an elaborate preface, the author points out the great want of such a piece of mechanism, its utility, and properties; and concludes with saying, that this machine, so big with advantages to music and musicians, is the *particular invention*, Besondere Erfindung, of M. Unger.

The description preceded the execution some time. The invention was here only recommended to the public, and offered to be completed, and applied to a keyed instrument, at a small expence. It was M. Hohlfeld who afterwards constructed the machine, and rendered it so perfect, that we were assured by a great performer, who tried it upon a clavichord, that there was no refinement in music which it could not express, except *tempo rubato*.

The description of the Berlin machine so much resembles that proposed by Mr. Creed, that we shall not insert it here, but refer our readers to the Philosophical Transactions, where he will find that the machine was to consist of two cylinders, which were to be moved by clockwork, at the rate of an inch in a second of time; one of these was to furnish paper, and the other was to receive it when marked by pins or pencils, fixed at the ends of the several keys of the instrument to which the machine was applied. The paper was to be previously prepared with red lines, which were to fall under their respective pencils.

The chief difficulties in the execution, which have occurred to English mechanics, with whom we have conversed on the subject, were, the preparation of the paper for receiving the marks made by the keys; and the kind of instrument which was to serve as a pencil, and which, if hard and pointed, would, in the *forte* parts, tear the paper; and if soft, would not only be liable to break when used with violence, but would be worn unequally, and want frequent cutting.

In the Berlin machine the pencils were approximated according to Mr. Creed's idea, and made to terminate in a very narrow compass, so that paper of an uncommon size was not requisite; but it was not found necessary to prepare the paper, as proposed in the Philosophical Transactions; for the degree of gravity or acuteness of each sound was ascertained by a ruler applied to the marked paper, when taken off the cylinder.

About the year 1780, the late ingenious and marvellous mechanic Merlin, stimulated by the reports of this machine having been successfully constructed in Germany, and by our earnest recommendation of the undertaking, went to work, and apparently vanquished all the difficulties of construction, except the time inevitably necessary for its completion; as he was never able to simplify the mechanism so much as to render its appropriation within the reach of great composers and voluntary players in general, to whose use only it seems to belong; he disposed of his model to a foreign nobleman, who had it conveyed to Germany, and we believe never fabricated another machine of the same kind. See Merlin.

Machine, in *Dramatic Poetry*, is when the poet brings some divinity or supernatural being upon the stage; to perform some exploit, or solve some difficulty, out of the reach of human power.

The machines of the drama are gods, angels, ghosts, &c. They are so called from the machines or contrivances by which they are represented upon the stage, and afterwards removed again.

Hence the use of the word machine has also passed into the epic poem; though the reason of its name be there wanting. It denotes, in both cases, the intervention or ministry of some divinity; but as the occasion of machines in the one and the other is somewhat different, the rules and laws of managing them are different likewise.

The ancient dramatic poets never brought any machine on the stage, but where there was an absolute necessity for the presence of a god; and they were generally laughed at for suffering themselves to be reduced to such a necessity. Accordingly, Aristotle lays it down as an express law, that the unravelling of the piece should arise from the fable itself, and not from any foreign machine, as in the Medea. Horace is somewhat less severe, and contents himself with saying, that the gods should never appear, unless where the *nodus*, or knot, is worthy of their presence; "Nec deus intersit, nisi dignus vindice nodus—inciderit." But it is quite otherwise with the epopea; in that there must be machines every where, and in every part. Homer and Virgil do nothing without them. Petronius, with his usual fire, maintains, that the poet should deal more with the gods than with men; that he should every where leave marks of his prophetic raptures, and of the divine fury that possesses him; that his thoughts should be all full of fables, that is, of allegories and figures: in fine, he will have a poem distinguished from a history in all its parts; not so much by the verses, as by that poetical fury, which expresses itself wholly by allegories; and does nothing but by machines, or the ministry of the gods. A poet, therefore, must leave it to the historian to say, that a fleet was dispersed by a storm, and driven to foreign shores; and must himself say, with Virgil, that Juno went to seek Æolus: and that this god, at her request, turned the winds loose against the Trojans: he must leave the historian to write, that a young prince behaved with a great deal of prudence and discretion on all occasions; and must say, with Homer, that Minerva led him by the hand in all his enterprizes: let an historian say, that Agamemnon, quarrelling with Achilles, hath a mind to shew him, though mistakenly, that he can take Troy without his assistance; the poet must say, that Thetis, piqued at the affront her son had received, flies up to heaven, there to demand vengeance of Jupiter: and that this god, to satisfy her, sends the god Somnus, or Sleep, to Agamemnon,

to deceive him, and make him believe that he ſhall take Troy that day.

It is thus that the epic poets uſed machines in all parts of their works; in the Iliad, Odyſſey, and Æneid, the propoſition mentions them; the invocation is addreſſed to them; and the narration is full of them: they are the cauſes of actions; they make the knots, and at laſt they unravel them. This laſt circumſtance is what Ariſtotle forbids in the drama; but it is what Homer and Virgil have both practiſed in the epopea. Thus Minerva fights for Ulyſſes againſt Penelope's lovers; helps him to deſtroy them; and, the next day, herſelf makes the peace between Ulyſſes and the Ithacans; which cloſes the Odyſſey. The uſe of machines in the epic poem is, on ſome accounts, entirely oppoſite to what Horace preſcribes for the theatre. In tragedy, that critic will never have them uſed without an abſolute neceſſity; whereas, in the epopea, they ſhould never be uſed, but where they may be as well let alone; and where the action appears as if it did not neceſſarily require them. How many gods and machines does Virgil implore to raiſe the ſtorm that drives Æneas into Carthage; which yet might eaſily have happened in the ordinary courſe of nature.

In Milton's Paradiſe Loſt, moſt of the actors are ſupernatural perſonages; and in Voltaire's Henriade, the poet has made excellent uſe of St. Louis.

Machines, in the epic poem, therefore, are not contrivances of the poet, to recover himſelf after he has made a falſe ſtep, nor to ſolve any difficulty peculiar to ſome part of the poem; but it is the preſence of a divinity, and ſome ſupernatural and extraordinary action, which the poet inſerts in moſt of the incidents of his work, to render it more majeſtic and admirable, and to train up his readers to piety and virtue. This mixture ſhould always be ſo managed, as that the machines may be retrenched, without retrenching any thing from the action. As to the manner in which the machines are to act; it may be obſerved, that in the old mythology, there are gods both good, bad, and indifferent; and that our paſſions may be converted into ſo many allegorical divinities: ſo that every thing, both good and bad in a poem, may be attributed to theſe machines, and may be tranſacted by them. They do not, however, always act in the ſame manner; ſometimes they act without appearing, and by ſimple inſpirations, which have nothing in them extraordinary or miraculous; as when we ſay, the devil ſuggeſted ſuch a thought, &c. The ſecond manner of acting is entirely miraculous; as when a divinity preſents itſelf viſible before men, ſo as to be known by them; or when they diſguiſe themſelves under ſome human form without diſcovering themſelves. The third manner partakes of each of the two, and conſiſts in oracles, dreams, and extraordinary inſpirations: all which Boſſu calls *demi-machines*.

All theſe manners ought to be ſo managed as to carry a veriſimilitude: and though veriſimilitude be of a vaſt extent in machines, as being founded on the divine power, yet it has its bounds. See farther, on the importance and uſe of machinery, the article Epic *Poem*.

Machine, in *Agriculture*, a term applied to inſtruments of various kinds which are contrived either for the purpoſe of leſſening labour or performing the different operations and proceſſes of the art with greater accuracy and correctneſs, ſuch as thoſe of ſowing, drilling, reaping, threſhing, winnowing, and a great many others. The term is moſt commonly employed when the nature of the tool is of the more complex kind. It may, however, be employed with propriety in many other circumſtances. See Threshing *Machine*.

Machine, *Architectonical*, is an aſſemblage of pieces of wood ſo diſpoſed, as that, by means of ropes and pullies, a ſmall number of men may raiſe vaſt loads, and lay them in their places. Such are cranes, &c.

It is hard to conceive what ſort of machines the ancients muſt have uſed to raiſe thoſe immenſe ſtones found in ſome of the antique buildings. See Machine, *ſupra*.

Machine, *Blowing*. See Bellows, and Blowing *Machine*.

Machine, *Bruiſing*, a contrivance for the purpoſe of cruſhing and reducing grain, pulſe, malt, and other articles, ſome of which are employed as team food. Machines of this kind are made in London by Rowntree and others.

Machine, *Chaff-cutting*, a tool contrived for the purpoſe of cutting ſtraw, hay, and other ſimilar materials into chaff for the purpoſe of food for team-horſes, and other animals. There are various deſcriptions of this kind of machinery which act on very different principles, and ſome of them have lately undergone very much improvement. See Chaff-cutter.

Machine, *Draught*, a ſimple contrivance formed for the purpoſe of aſcertaining the force or power of draught, in drawing ploughs, and various other implements where draught is required. A machine of this ſort, invented by Mr. More, late ſecretary to the Society for the Encouragement of Arts, &c. in London, is thus deſcribed by Mr. Young in the firſt volume of the Annals of Agriculture. It is a ſpring coiled within a cylindrical caſe, having a dial-plate, marked with numbers like that of a clock, and ſo contrived that a hand moves with the motion of the ſpring, and points to the numbers in proportion as the force is exerted: for inſtance, when the draught equals 1 cwt. over a pulley, the hand points to *fig.* 1; when the draught is equal to 2 cwt. it points to *fig.* 2; and ſo on. Till this very uſeful machine was invented, Mr. Young ſays, it was exceedingly difficult to compare the draught of different ploughs, as there was no rule to judge but by the exertions of the horſes as apparent to the eye; a very indeciſive mode of aſcertaining their force.

Machine, *Drill*, that ſort of tool which is employed in ſowing and depoſiting various kinds of grain, pulſe, and ſmall ſeeds, in drills or rows. They are very differently formed, according to the purpoſes for which they are intended, and the manner of drilling which is intended to be practiſed.

They require to be conſtructed with great correctneſs, and in as ſimple a manner as poſſible, in order that they may perform their work with accuracy, both in reſpect to the drills, the quantity of ſeed, and the depth of depoſiting it in the ſoil.

In the choice of this ſort of machinery, the farmer ſhould be principally directed by the nature and extent of his land, the ſituation which it poſſeſſes, and the kinds of crops which he intends to cultivate. They have lately been ſo contrived, as, by ſlight alterations in the ſowing parts, to be capable of not only ſowing grain as well as ſmall ſeeds, but of executing the work at different diſtances, and in a greater or leſs number of rows at once, as circumſtances may require.

There are ſeveral machines of this nature, which perform the buſineſs in a very exact and regular manner; among which are Cook's, Bailey's, Amoſe's, M'Dougal's, and many others; each of which ſow ſeveral rows at the ſame time, and ſome of them are likewiſe capable of forming horſe-hoes.

Beſides theſe, there are alſo drills conſtructed for parti-

cular forts of crops, as thofe of peas, beans, turnips, &c. See PLOUGH *Drill*, and TURNIP *Drill*.

A drill machine, invented by Mr. Robert Salmon of Woburn, Bedfordfhire, which obtained the premium given by the duke of Bedford, at Woburn fheep-fhearing, a few years ago, for the beft newly-invented agricultural implement, is defcribed below. This machine drills and fows at the fame time; and the principal improvement in it, as in Cook's drill, and others, confifts in conftructing it in fuch a manner, that the workman who holds the drill has a perfect command upon it, with refpect to the direction in which it fhall move, even though the horfe which draws it fhould deviate from the line the drill is intended to follow. In *Plate (Machines) Agriculture*, is given a defcriptive reprefentation of the machine, in which *fig.* 1 is a fection of a part, *fig.* 2 an elevation of the fame, *fig.* 4 is a perfpective view of the whole, and *figs.* 3 and 5 detached parts.

The great wheels, A, A, *fig.* 4, have their axle-trees attached to the bed B, to which are framed the long handles, D, D, forming a frame independent of the remainder of the machine, and having no connection with it, except in the middle of the bed B, where a fhort beam, E, is jointed to it, as is well explained in *fig.* 1; the other end of this beam is mortifed into a crofs beam F, to which the three drills, G, G, G, are fixed; a frame formed of two horizontal pieces, H, H, *figs.* 2 and 4, and four vertical pieces, I, I, I, I, is erected upon F; the handles, D, D, pafs between H, H, but are not fixed thereto; the hook *a*, by which the machine is drawn, is fixed to the two middle uprights, I, I, and a ftrong chain leads to the harnefs of the horfe employed; K is the feed-box fupported from H, H, by two uprights for the purpofe; the box is a fruftum of a pyramid, and joins at the bottom to a prifmatic box, containing the feed-roller *b*, *fig.* 1, which is exactly the fame length as the box, and comes through its ends, its pivots being fupported by a piece of iron-plate fixed at the end of the box, as feen in *fig.* 4; a brufh, *d*, preffes upon the roller, and is adjuftable by a fcrew that it may always bear upon it with an equal degree of force; a number of notches is cut in the circumference of the roller, and as the box K is full of feed, it always refts upon the roller; when it turns round, it takes one of the notches full of feed, and paffing it by that means under the end of the brufh *d*, delivers it into a tin-plate tube *r*, which conveys it down into the furrow made by the drill; the roller has three feries of notches anfwering to the three drills G, G, G; at *e*, a piece of leather preffes againft the roller, to prevent any feed getting down, except that which paffes under the brufh *d*; *f* is a flider, which ftops the feed from coming down to the roller, when fhoved in, and is ufed when the machine is required to advance without fowing, or when a leffer number of rows is required to be fown. The roller is turned by means of an endlefs chain, *q q*, paffing round a groove made in the middle of the roller, from thence it proceeds through a block of pullies at *t*, fhewn feparate in *fig.* 5, to a fmall wheel *h*; the block, *t*, is made of caft-iron, and flides freely up and down between the two innermoft uprights, I, I, of the frame; its weight keeps the chain always tight, and prevents it from flipping without turning the roller; the wheel, *h*, is fixed upon an axle *p*, on the end of which is a cog-wheel, turned by another cog-wheel on the nave of the great wheel A; thefe wheels are enclofed in a box *k*, which likewife contains a contrivance for difengaging the wheels, fhewn on a larger fcale in *fig.* 3, where *p* is a fection of the axle *p*, paffing through a long ftaple fixed to the bed B; it can flide up and down in this ftaple, except when confined by a catch *o*, preffed againft it by a fpring. In the prefent pofition, the cog-wheels are engaged to work together: but by pulling the cords *m* and *l*, the former draws back the catch *o*; and the other, by means of the crooked lever *n n*, raifes up the axle *p*, and difengages the cog-wheels; the return of the catch, *o*, prevents its defcent; the cords, *l* and *m*, are conducted to the end of the handles, D, D where they are both attached to one handle, in reach of the workman who guides the machine.

The operation of the drill is exceedingly fimple. As the horfe draws it along by means of the chain, the drills, G, G, G, make the furrows, and the feed-roller delivers the feed in fmall quantities, and at regular intervals into them. As the hook *a*, from which the chain draws, is placed nearly in the centre of the machine, it will eafily be made to follow any other line than that in which the horfe draws, by turning the handles, D, D, to one or other fide. This alters the direction of the wheels, A, A, which immediately proceed in that line, and the drill follows them. This quality is of the greateft confequence in making ftraight work. L is a crofs piece fixed to the handles, D, D, and fupporting a handle M, by which, and one of D, the workman holds when he guides the drill, as he is then in a pofition to fee the drills made laft, and adapt the prefent ones to them; the wheel always going in the laft made drill. Another handle, fimilar to M, is fixed to the other end of L, to be ufed when the machine is on the other fide of the work done laft. The drills are fixed to the piece F by fcrews, and their diftance from one another can be altered at pleafure. The feed-box containing the roller is made in two halves, connected by hooks, fo that it can be taken apart, and the roller removed for a frefh one to be put in with different fized notches, for fowing a different kind of grain.

The drawing was taken from a machine made by Mr. Shepherd, Woburn, and exhibited at Woburn fheep-fhearing, June 1808. Mr. Salmon has made a great number of the fame pattern, which are now in ufe, and are found to anfwer well. Several of them have five drills inftead of three, and are in that cafe worked by one horfe.

In this drill, at whatever diftance the fhares are placed to go from each other, the diftance from the wheels to the two outfide rows is alway equal thereto; confequently, when at work, one or the other of the wheels always runs in the laft made drill, thereby guaging accurately the interval between each bout the drill goes; and as the holder always goes in the line of the wheel, he can diftinctly fee and correct the fmalleft error that may have been made in any previous bout.

In all cafes, one horfe is fufficient to draw this drill either for three or more rows, as little depends on the horfe's inclination; and a driver can be difpenfed with, where tractable horfes are ufed. As in all machines of this fort, in proportion to the number and diftance of rows made, fo will be the quantity of work performed.

MACHINE, *Electrical*. See ELECTRICAL *Machine*.

MACHINE, *Fan*, in *Agriculture*, a common name applied to that fort of tool which is employed in removing the chaff from the grain. See WINNOWING *Machine*.

MACHINE, *Land-Levelling*, the name of an ufeful machine, invented by Mr. David Charles, for the purpofe of rendering high ridges and other inequalities, in fuch lands as are in a ftate, more level and even in their furfaces. It would feem probable that no effective implement of this fort has hitherto been introduced. But fuch a machine is faid, in "Tranfactions of the Society of Arts," to be ufeful and neceffary even in the moft fertile parts of the country, where the improved fyftem of drill-hufbandry has

been introduced, or even where there is any attention to the waſte of time, or to the eaſe of cattle in the act of ploughing; in order to get rid of crooked or unequal ridges, without either a ſummer fallow by croſs ploughing, or elſe by frequent repetitions of ploughing in the winter and ſpring, which the humidity of this climate will not allow in every kind of ſoil. "Fourteen acres of land were reduced with this tool by the inventor to a perfect level, where the crowns of the ridges were about two feet higher than the furrows, and where they were crooked and of unequal breadths. But the chief ſucceſs has been upon a field of eight acres, which lay in an unprofitable ſtate, and which is a deep clay, that had produced a crop of wheat from an old lay ſod the former year, without any manure, which was winter ploughed, and lay in that ſtate until the machine was introduced the firſt dry weather in April. It was preceded by two horſe ploughs, taking perhaps a ſquare of an acre at once: theſe looſened the ſoil the depth of a common furrow, and twice the breadth acroſs the ridges. The levelling machine followed, drawn by two oxen and two horſes, with a man at each handle, to preſs it down where the height was to be removed, and to lift up the body by the handles where it was to be diſcharged. Thus, four men, one driver, and eight head of cattle, will more effectually level from half an acre to three roods in one day, according as the earth is light or heavy, than ſixty or eighty men would accompliſh with harrows and ſhovels, &c. even with the aſſiſtance of a plough. In ſandy ground, where the depth of one furrow will bring all to a level, as much, of courſe, will be done in one day as two ploughs can cover;" but in this caſe, the ground required to be gone over ſeveral times. It is further ſtated, that "after this field was levelled, the backs of the ridges, as they are termed, which were ſtripped of their vegetable mould, were ploughed up, the furrows not requiring it. They were alſo harrowed, and the field copiouſly manured with lime-compoſt, harrowed in, and broke into nine feet ridges, perfectly ſtraight, in order to introduce Duckit's drill. It was ſown under furrow, broad-caſt, the laſt of it not until the 13th of May, and was cut down a reaſonable crop the 4th of September." And "the field now lies in proper form, well manured, with the advantage of a fair crop from heavy tenacious ground, without loſing a ſeaſon, and in a year by no means favourable." The writer is "well aware there are many ſhallow ſoils, where it may be hazardous to remove the enriched ſurface, and truſt perhaps one half of the land for a crop that had never before been expoſed to the atmoſphere; but where the ſoil is ſufficiently deep, or there is a good under-ſtratum, with manure at hand to correct what is ſour for want of expoſure and tillage, it is evident, from this experiment, that no riſk is run." And in order "to avoid the expence of a fallow, and to lay out ground in ſtraight and even ridges, even where drill huſbandry is not practiſed, ſhould be objects to every rational farmer: but where the new ſyſtem is intended to be adopted, it becomes indiſpenſibly neceſſary. In laying down lawns, parks, &c. where furrows are an eye-ſore, or places inacceſſible to wheel-carriages from their declivity, and from which earth is to be removed, it will alſo be found equally uſeful." Beſides theſe, there are many other caſes in which the old rounded ridges may be levelled down with great advantage, either by this or ſome other means.

A repreſentation of this machine is given at *fig.* 1. in *Plate (Machines) Agriculture*, in which *a*, *fig.* 2. is a part of the pole, to which the oxen or horſes which draw the machine are faſtened, and which is attached to the machine by a pin at *b*; *c*, *c*, the two wheels, ſhod with iron, which run upon the axle *d*; *e e*, the upper frame-work of the machine, extending from the axle to the extremity of the handles, *f*, *f*, and ſecured firmly by the croſs pieces, *g*, *g*, the curved iron ſliders of the machine, which may be raiſed or depreſſed a little by means of the pins, *h*, *h*, which paſs through holes in the wood-work, and alſo in the iron ſliders. Theſe ſliders form one piece with the back iron ſcraper *i*, in the manner more fully explained in *fig.* 3, *k*, the wooden back of the machine, which ſhould be made ſtrong, to reſiſt the weight of the earth when collected therein. The iron ſcraper ſhould be firmly ſecured to this by ſcrews and iron work; *l*, *l*, the wooden ſides of the machine, firmly connected with the back and frame work, in order to aſſiſt in collecting the earth to be removed; *m*, a ſtrong croſs piece, into which the ribs which ſupport the back are well mortiſed.

The interior part of the back of the machine is ſhewn at *k*, in *fig.* 3: *i*, the iron ſcraper, ſharp at the bottom, firmly ſcrewed to the back of the machine; *g*, *g*, parts of the ſide irons or ſliders, ſhewing the mode in which they are united with the ſcraper *i*; *m*, the croſs piece already deſcribed.

Machines, *Military*, among the *Ancients*, were of three kinds: the firſt ſerving to launch arrows, as the ſcorpion; or javelins, as the catapulta; or ſtones, as the baliſta; or fiery darts, as the pyrabolus: the ſecond ſerving to beat down walls, as the battering ram and terebra: and the third to ſhelter thoſe who approach the enemies wall, as the tortoiſe or teſtudo, the vinea, pluteus, and the towers of wood. Theſe machines, together with their proportions and properties, are deſcribed in the works of Vitruvius, Ammianus Marcellinus, and other writers. Mr. Groſe has given deſcriptions and drawings of theſe in the *firſt* volume of his "Military Antiquities," chap. xii.

Machine, *Stone-lifting*, in *Agriculture*, an implement of the triangle kind, ſimilar to that uſed by wood-cutters for weighing bark, conſtructed for the purpoſe of raiſing large ſtones of ſome tons weight uſed in the northern parts of Scotland, and many other places. It is ſuppoſed to ſave much expence in powder and boring as well as labour, three men being ſufficient to work it. It is deſcribed in the Agricultural Survey of Perthſhire in this manner

"The three legs, *a d*, *b d*, and *c d*, which are ſhewn at *fig.* 4, are beams of any hard wood, four inches thick, ſix inches broad, and about fourteen feet long. Their thinneſt ſide points inwards, which gives them more ſtrength. Their feet form on the ground an equilateral triangle *a b c*, and their three tops at *d* are fixed together by an iron rod, which paſſes through each. The two legs *a d* and *b d* are fixed to one another by the windlaſs *k*, and by the croſs-bar *o p q*. There are two pullies *e* and *f*, with an iron hook two inches in circumference to each; *g g g* may be (more than one, but rather) one iron chain which goes round the ſtone *n*, while lying in the ground at *m*, below its greateſt diameter, or where it begins to become narrow. This chain conſiſts of rounded links, which are about three inches long, and about the thickneſs of a man's little finger. It has a hook at one end, that may be put into any link towards the other end, which will make it embrace the ſtone exactly, and be of the ſame circumference, where the ſtone touches the earth; *h g*, *h g*, *h g*, are ſhorter chains of the ſame workmanſhip, whoſe hooks are fixed into links of the ſurrounding chain at *g g g*, and ſo on round the ſtone, having the correſponding link of each fixed on the hook of the lower pulley at *h*. The whole rope muſt be of the ſame thickneſs with the two great hooks, two inches in circumference.

"All things being thus prepared, two men turn round the handles of the cylinder, and the waggoner aſſiſting them

by applying a lever to any side of the stone that seems to be firmest, they force it aloft, and hold it up at the proper height, until the driver put his carriage backward between *b* and *c*, which carriage ought to have a strong frame upon four low stout wheels; then the stone is let gently down and carried away."

By this sort of machine large stones or other bodies can be raised and removed without any great difficulty.

MACHINE, *Threshing*, a contrivance made use of instead of the flail for threshing corn and other seed crops. See THRESHING *Machine*.

MACHINE, *Water*, or *Hydraulic*, is either used to signify a simple machine, serving to conduct or raise water; as a sluice, pump, &c. or several of these acting together, to produce some extraordinary effect; as the

MACHINE *of Marli*. See MARLI. See also FIRE-*engine*, STEAM-*engine*, and WATER-*works*.

MACHINE, *Water-raising*, a sort of machine contrived for the purpose of raising water a few feet high by the power of the *wind*, for the purpose of draining morasses, or of watering lands on a higher level, and other similar uses. A section of it is given at *fig.* 5, and it is described by the author of the Philosophy of Agriculture and Gardening to "consist of a windmill sail placed horizontally, like that of a smoke-jack, surrounded by an octagon tower; the diverging rays of this tower, *a b*, *a b*, may consist of two-inch deals only, if on a small scale, or of brick-work if on a larger one. These upright pillars are connected together by oblique horizontal boards at A B, by which boards placed horizontally from pillar to pillar in respect to their length, but at an angle of about 45 degrees in respect to their breadth, so as to form a complete octagon, including the horizontal windmill sail near the top of it; the wind, as it strikes against any of them, from whatever quarter it comes, is bent upwards, and then strikes against the horizontal wind-sail. These horizontal boards, which form the sides of the octagon, may either be fixed in their situations, or be made to turn upon an axis a little below their centres of gravity, so as to close themselves on that side of the octagon tower most distant from the wind. It may be supposed that the wind thus reflected, would lose considerably of its power before it strikes on the wind-sail; on fixing a model of such a machine, however, on the arm of a long whirling lever, with proper machinery to count the revolutions of the wind-sail, when thus included in a tower, and moving horizontally; and then when moved vertically, as it was whirled on the arm of the lever with the same velocity, it was found on many trials by Mr. Edgeworth, in Ireland, and Dr. Darwin, at Derby, that the wind, by being thus reverted upwards by a fixed planed board, did not seem to lose any of its power. And as the height of the tower may be made twice as great as the diameter of the sail, there is reason to conclude, the doctor thinks, that the power of the horizontal wind-sail may be considerably greater, than if the sail was placed nearly vertically opposed to the wind in the usual manner. At the bottom of the shaft of the wind-sail is placed a centrifugal pump with two arms at D, C, which consists simply of an upright bored trunk, or cylinder of lead, with two opposite arms with an adapted valve at the bottom to prevent the return of the water, and a valve at the extremity of each arm to prevent any ingress of air above the current of the water as it flows out; *c c c c* is a circular trough to receive the streams of water from C and D, to convey them where required in any particular operation or process.

And at *fig.* 6 is another machine, invented by Mr. Sergeant, of Whitehaven, calculated for raising or forcing water in particular cases, as for domestic or other uses. It is extremely simple and cheap in its construction, the whole, exclusive of the pump pipes, &c. not costing more than five pounds. The object for which it was particularly contrived was that of raising water for the supply of a gentleman's house from a stream running at the distance of about 140 yards. In which intention a dam was made a little distance above, so as to cause a fall of about four feet, the water being brought by a wooden trough, into which was inserted a piece of two-inch leaden pipe, a part of which is seen at *a*, in the figure; the stream of this pipe is so directed as to run into the bucket *b c*, when the bucket is elevated; but as soon as it begins to descend, the stream flows over it, and goes to supply the wooden trough, or well, in which the foot of the forcing pump, *c*, stands, of three inches bore; *d* is an iron cylinder attached to the pump rod, which passes through it, which is filled with lead, and is in weight about 240 pounds. This is the power which works the pump, forcing the water through 240 feet of inch pipe from the pump up to the house. At *e* a cord is fixed, which, when the bucket comes to within four or five inches of its lowest projection, becomes stretched, and opens a valve at the bottom of it, through which the water discharges itself. This sort of pump may be found very beneficial in a variety of instances where its application can be admitted.

MACHINE, *Wind*. See ANEMOMETER, and WIND *Machine*.

MACHINERY, in the Lyric theatre, or Opera-house. In the early operas of Italy, during the 17th century, it seldom happened that the names of the poets, composers, or singers, were recorded in printed copies of the words; though that of the machinist was seldom omitted; and much greater care seems to have been taken to amuse the eye than the ear or intellect of those who attended these spectacles.

In 1675, we are told, in the Theatrical Annals of Venice, that a musical drama, called La Divisione del Mondo, written by Giulio Cesare Corradi, and set by Legrenzi, excited universal admiration, by the stupendous machinery and decorations with which it was exhibited. And in 1680, the opera of Berenice, set by Domenico Freschi, was performed at Padua in a manner so splendid, that some of the decorations recorded in the printed copy of the piece seem worthy of notice in this article. The musical drama consisted of poetry, music, dancing, machinery, and decorations; and it would be curious to point out the encroachments which any one of these constituent parts at different periods has made upon the rest. In the beginning it was certainly the intention of opera legislators to favour Poetry, and make her mistress of the feast; and it was a long while before Music absolutely took the lead. Dancing only stept into importance during the last century; but very early in the 17th century, machinery and decorations were so important, that little thought or expence was bestowed on poetry, music, or dancing, provided some means could be devised of exciting astonishment in the spectators, by splendid scenes and ingenious mechanical contrivances.

In the opera of Berenice just mentioned, there were choruses of one hundred virgins, one hundred soldiers, one hundred horsemen in iron armour, forty cornets of horse, six trumpeters on horseback, six drummers, six ensigns, six sacbuts, six great flutes, six minstrels playing on Turkish instruments, six others on octave flutes, six pages, three serjeants, six cymbalists, twelve huntsmen, twelve grooms, six coachmen for the triumph, six others for the procession, two lions led by two Turks, two elephants by two others, Berenice's triumphal car drawn by four horses, six other cars with prisoners and spoils drawn by twelve horses, six

coaches for the proceffion. Among the fcenes and reprefentations in the firft act, was a vaft plain, with two triumphal arches; another, with pavilions and tents; a fquare prepared for the entrance of the triumph; and a foreft for the chace. Act II. the royal apartments of Berenice's temple of vengeance; a fpacious court, with a view of the prifon; and a covered way for the coaches to move in proceffion. Act III. the royal dreffing room, completely furnifhed; ftables with one hundred live horfes; portico adorned with tapeftry; a delicious palace in perfpective. And befides all thefe attendants and decorations, at the end of the firft act, there were reprefentations of every fpecies of chace: as of the wild boar, the ftag, deer, and bears; and at the end of the third act, an enormous globe defcends from the fky, which opening divides itfelf into other globes that are fufpended in the air, upon one of which is the figure of Time, on a fecond that of Fame, on others, Honour, Nobility, Virtue, and Glory. Had the falaries of fingers been at this time equal to the prefent, the fupport of fuch expenfive and puerile toys, would have inclined the managers to enquire, not after the beft, but the cheapeft vocal performers they could find; as fplendid ballets often oblige them to do now; and it is certain, that during the 17th century, the diftinctive characteriftic charm of an opera was not the mufic, but machinery. The French eftablifhed mufical dramas in their court and capital during the rage for mythological reprefentations, to which they have conftantly adhered ever fince; and when they are obliged to allow the mufical compofition and finging to be inferior to that of Italy, they comfort themfelves and humble their adverfaries by obferving, that their opera is, at leaft, a fine thing to fee: "c'eft au moins un beau fpectacle, qu'un opera en France."

MACHINERY, in *Mechanics*, may be confidered as the operative and moving parts of machines; it is, however, very generally, though perhaps improperly, applied to include all the parts of machines, fixed as well as moving, and in this view may be confidered as the inftruments or parts by which the principles of mechanics are carried into execution, and rendered applicable to all the purpofes of arts and manufactures.

The denomination machine is now vulgarly given to a great variety of fubjects that have very little analogy by which they can be claffed with propriety under one name: we fay a travelling machine, a bathing machine, a copying machine, a threfhing machine, an electrical machine, &c. &c. The only circumftances in which all thefe agree, feem to be, that their conftruction is more complex and artificial than the utenfils, tools, or inftruments which offer themfelves to the firft thoughts of uncultivated people; they are more artificial than the common cart, the bathing tub, the flail, or the glafs tube which firft difcovered the phenomena of electricity. In the language of ancient Athens and Rome, the term was applied to every tool by which hard labour of any kind was performed; but in the language of modern Europe, it feems reftricted either to fuch tools or inftruments as are employed for executing fome philofophical purpofe, or of which the conftruction employs the fimple mechanical powers in a confpicuous manner, fo that their operation and energy engage the attention. It is nearly fynonimous, in our language, with *engine*; a term altogether modern, and in fome meafure honourable, being beftowed only, or chiefly, on contrivances for executing work in which ingenuity and mechanical fkill are manifeft. Either of thefe terms, machine or engine, is applied with impropriety to contrivances in which fome piece of work is not executing on materials, which are then faid to be manufactured. A *travelling* or *bathing* machine is furely a vulgarifm.

A machine or engine is, therefore, a tool, but of complicated conftruction, peculiarly fitted for expediting labour, or for performing it according to certain invariable principles: and we fhould add, that the dependence of its efficacy or mechanical principles muft be apparent, and even confpicuous.

The contrivance and erection of fuch works conftitute the profeffion of the engineer; a profeffion which ought by no means to be confounded with that of the mechanic, the artifan, or manufacturer. It is one of the *Artes liberales*; as deferving of the title as medicine, furgery, architecture, painting, or fculpture. Nay, whether we confider the importance of it to this flourifhing nation, or the fcience that is neceffary for giving eminence to the profeffor, it is very doubtful whether it fhould not take place of the three laft named, and go *pari paffu* with furgery and medicine.

In the language of our practical mechanics, the terms *machine*, *engine*, and *mill*, are ufed without a proper diftinction of the claffes of machinery to which they fhould in ftrictnefs be applied. All thefe denominations are alike the practical applications of the fcience of mechanics, and confift only of different combinations of the mechanical powers. Though the combinations and modifications which the ingenuity of mankind is conftantly producing are endlefs, ftill it is poffible, by a proper claffification, to arrange them under their proper terms, to avoid the confufion which at prefent prevails amongft thofe of our ingenious countrymen, who have laboured to improve the arts dependent on mechanics, without troubling themfelves to fix upon the moft precife language in which to exprefs their ideas. If we might prefume to decide upon a proper definition of thefe words, which has not hitherto been done, we fhould advife that the term machine be ufed as generic, and applied to any mill, engine, inftrument, or apparatus having moving parts. That machinery fhould alfo be ufed as a general term, fignifying the moving and operative parts of any machine or engine whatever, and its fynonimous term mechanifm be applied to the moft delicate machinery, fuch as the parts of watches and mathematical inftruments, or to the moft delicate parts of any other machine, as the machinery of a flour-mill, or fawing-mill; the mechanifm of a clock, watch, orrery, &c.

Let the term *engine* be reftricted to fuch machines as have fome relation to hydraulics or pneumatics, or, in fhort, where their operations depend upon, or actuate fluids; as a fteam engine, a water engine, pumping engine, blowing engine, preffure engine, and fire extinguifhing engine.

Mill fhould be applied to large and powerful compound machines, or fyftems of machines; including their firft mover in the term; as a cotton mill, which contains a vaft number of different machines, and alfo the water wheel, or fteam engine, which actuates them all; fo likewife, an iron mill, copper mill, rolling mill, grinding mill, logwood mill, worfted mill, &c. &c.

Corn mill, or *flour mill*, is, in fome degree, an exception to our definition, becaufe in the early ftages of fociety it was the only mill in ufe, and hence the term became particularly attached to it; and any machine for grinding or reducing to powder is called a mill, as a coffee mill, bark mill, colour mill, malt mill, &c. though, in ftrictnefs, thefe fhould be called machines.

In this claffification, we have ftudied to infringe as little as poffible upon the diftinctions which have been made by cuftom, and confirmed by the ufage of mechanics themfelves, though not invariably, for they have dividing engines, cutting engines, and many others which fhould be machines.

The practical application of mechanics to the construction of machinery, is a subject of the utmost importance to the welfare of our country, depending so materially as it does upon commerce, which is derived chiefly from our manufactures; and these owe the pre-eminence they have over other nations to the general introduction of machinery, which has taken place within these forty years, to abridge manual labour in every department, and in every trifling operation: it is to this source we must look for the increase of property of every description, as the introduction of every machine is a real creation of all the work it will perform, without the addition of farther increase of human labour. An idea is very generally entertained, that machinery is prejudicial to the interest of mankind, as far as it tends to diminish the value of that labour by which the lower classes of society can alone purchase the means of subsistence: this idea is, however, founded on error, as applied to any supposed injury society in general can sustain, though individuals whose labours are superseded by machines, will suffer inconvenience for a time, yet it is only for a time, and so long as they, or others more intelligent, shall discover a new channel for the exertion of their industry. As machines tend to increase the quantities of those luxuries and necessaries of life which mankind are so anxious to obtain, it only requires that an equitable division of these benefits should be made to obviate every objection, and really improve the condition of all classes; a retrospect of the last forty years shews the truth of this observation, for though so many machines have been employed in all trades and manufactures as probably to do more work than the whole population could do previous to that period, yet the value of human labour has, notwithstanding, increased in the same proportion as other articles have advanced in price.

We shall, in this article, enter into some general observations upon the construction of machinery, and particularly point out such contrivances as seem applicable to other purposes than those for which their inventors have employed them; and we shall give, as examples of practical machinery, a description of the famous block machines at Portsmouth, which contain many new contrivances. We were unable to introduce these under the article BLOCK, as the machines were not erected at the time that article was printed.

The grand object of all mechanism, or machinery, is to convey and modify the motion of the first mover of the machine, and communicate it in a proper manner to the subject to be operated upon: thus, the slow rotative motion of a water-wheel is, by the machinery of cranks, levers, and toothed wheels, converted into a rapid reciprocating motion for working sawing machines, and the velocity of the motion is increased or diminished, as the occasion requires either great power or great speed. In like manner, the rectilinear motion of the piston rod of a steam engine is, by the machinery of parallel levers, working-beam, connecting-rod, crank and fly-wheel, converted into a rotative motion; and this motion can again, by the machinery of wheel-work, be adapted, either in velocity or power, to work grinding-stones, circular saws, threshing-mills, and other similar machines which require great velocity; or flatting mills, boring machines, rasping machines for logwood, lead-pipe drawing machines, &c. which require great power to give them motion, and are, therefore, performed with a less velocity. Machinery is, therefore, the organs by which motion is altered in its velocity, its period, and direction, and thus adapted to any purpose. All machinery will be found, upon minute investigation, to be only modifications of the six mechanical powers: the greatest number will be found to consist chiefly of parts which have a motion of rotation round fixed axes, and derive all their energy from levers virtually contained in them: thus the pullies, wheel and axle, are only modifications of the lever, and the screw is compounded of the lever with a variety of the inclined plane or wedge, so that the number of mechanical powers may be reduced to two, which assume an infinite variety of forms and motions. The theory and manner of calculating their effects will be found under MECHANICS.

In contriving any machinery, the engineer should always remember that nothing contributes more to the perfection of a machine, especially if it is massive and ponderous, than great uniformity of motion. Every irregularity of motion wastes some of the impelling power; and it is only the greatest of the varying velocity which is equal to that which the machine would acquire if moving uniformly throughout; for while the motion accelerates, the impelling force is greater than what balances the resistance then actually opposed to it, and the velocity is less than what the machine would acquire if moving uniformly; and when the machine attains its greatest velocity, it attains it because the power is then not acting against the whole resistance. In both of these situations, therefore, the performance of the machine is less than if the power and resistance constantly bore the same relation to each other, in which case it would move uniformly.

Every attention should, therefore, be given to this, and we should endeavour to remove all cause of irregularity through the whole machine. There are continual returns of strains and jolts from the inertia of the different parts acting in opposite direction. Although the whole momenta may always balance each other, yet the general motion is hobbling, and the points of support are strained. A great engine, so constructed, commonly causes the building to tremble; but when uniform motion pervades the whole machine, the inertia of each part tends to preserve this uniformity, and all goes smoothly. It is also deserving of remark, that when the communications are so contrived, that the uniform motion of one part produces uniform motion to the next, the pressures at the communicating points remain constant or invariable. Now the accomplishing of this is generally within the reach of mechanics, and the engineer should adapt his machinery to the particular case before him.

In the machinery for modifying and adapting a rotatory motion, the first which presents itself is the communication by means of toothed wheels acting on each other. This is the most general method in machinery, because it transmits the motion with certainty and accuracy, and if the teeth are properly formed, wheels, perhaps, consume less force in friction than any other method; but this is a subject understood by few mechanics. In the treatises on the construction of mills, and other works of this kind, are many instructions for the formation of the teeth of wheels, and almost every noted millwright has his own nostrums; but they are most of them defective in principle, or at least they are only correct in certain cases, which have by experiment or theory been determined, and are extremely fallacious when applied indifferently for all cases, as is the millwright's custom. An investigation of this subject, as applied to delicate mechanism, where accuracy rather than strength is the object, will be found in our article CLOCK *Work*, and we propose to give some further applications of those principles to wheels of large dimensions under MILL *Work*.

In the formation of the teeth of wheels, a small deviation from the perfect form is not, perhaps, of very great importance, except in cases where a very large wheel

drives a very ſmall one, a caſe the judicious engineer ſhould always avoid: the grand point to be attended to, is to adopt ſuch a conſtruction as will inſure all the teeth of a wheel being preciſely equal, and to make as great a number of them as the ſtrength will admit. This will cauſe ſeveral teeth to be in action at once, and make the communication of the motion extremely ſmooth and uniform. To obtain ſtrength in the cogs when they are made fine, the width or thickneſs of the wheel muſt be increaſed; and this is one of the greateſt practical improvements which has been made in machinery for theſe laſt twenty years. Formerly the beſt engineers, ſuch as Smeaton, directed the teeth of large cog-wheels to be four and five inches diſtant from each other, or *pitch*, as the millwrights term it. Such wheels always act unequally upon each other in conſequence of the point of contact of the large cogs conſtantly altering its poſition, becoming alternately nearer or farther from the centre of one or other of the wheels; and this, tending to increaſe the acting radius of one, whilſt it diminiſhes the other, cauſes their velocity and powers to vary at every cog that paſſes by, and the machine works by ſtarts and jerks. The wheel-work of modern machinery is conſtructed with fine cogs, ſeldom more than one and a half or two inches pitch, and as much length of cog, or breadth of the wheel, as will make them ſufficiently ſtrong. We have ſeen ſome wheels in a large cotton mill which bore a ſtrain equal to thirty horſes' power, in which they were nine and twelve inches broad upon the face. Cog-wheels are found to work moſt ſmoothly when the teeth of the large wheel are made of hard wood, and the teeth of the ſmall one made of caſt iron, the acting ſurfaces being dreſſed or filed ſmooth and to the true figure. A mechanic, in contriving any machinery, ſhould always bear in mind, that where he introduces cog-wheels, they ſhould be as large in their diameters as is conſiſtent with other circumſtances, becauſe this allows the teeth to be made finer in proportion to the power they are to bear, than if they were of ſmaller radii; and the teeth, therefore, nearer the centre: it alſo occaſions leſs preſſure or drift upon the centre, and the wear of the whole will be equable. Another circumſtance is worth notice, and ſhould always be attended to, where it will not interfere with more important conſiderations; this is, the direction in which any force is given to, and taken from, any piece of wheel-work: ſuppoſe, for inſtance, a water-wheel turning its axis, upon which is fixed a cog-wheel to give motion to a ſecond wheel, for the purpoſe of driving any machinery; now if this ſecond cog-wheel is applied on that ſide of the firſt cog-wheel which is aſcending, it will be oppoſite to that ſide of the wheel which is loaded with water, and is conſequently deſcending. In this ſtate the gudgeons of the water-wheel will have to bear (in ſome caſes) double the ſtrain of the power of the machine; becauſe the power, which is the weight of the water, is applied on one ſide the centre of the wheel, and is taken off by turning the ſecond cog-wheel on the other ſide: the centre, or fulcrum, therefore, bears the whole power, and alſo the re-action to that power, in addition to the weight of its own parts; in the ſame manner as the fulcrum of a ſteelyard or balance beam bears the whole of the weight ſuſpended from either end, and its own weight alſo. On the other hand, ſuppoſe the ſecond wheel applied on the deſcending ſide of the water wheel, this being on the ſame ſide of the centre, the preſſure thereon will be far leſs than the power of the machine. In ſome caſes (but not in a water-wheel), by the proper arrangement of the wheel work, the power may be made to operate to lift the centres, and thus in part relieve them from the weight of the wheel, ſo as actually to diminiſh the preſſure of friction of the pivots, when, by a contrary application, it would have increaſed it in the ſame degree. Similar advantages will attend the precaution of adapting the poſitions of different wheels upon their ſhafts to the different weights or ſtrains they have to bear, ſo that the gudgeons at the two ends of any ſhaft may have an equal drift or preſſure upon them. This will cauſe them to wear equally, and to have leſs friction, becauſe they may be made ſmaller than where no ſuch care is taken, ſtill having ſufficient ſtrength. It is accompliſhed by conſidering the drift or preſſure upon the centre of every wheel upon any axis, and placing the two gudgeons or pivots of the axis at a diſtance from each of the wheels, proportionate to the drift upon its centre. Thus, ſuppoſe a ſhaft has a cog-wheel fixed upon it, and a ſmall wheel or pinion alſo fixed upon it at ſome diſtance from the wheel, the power is given to the axis by wheel-work operating upon the teeth of the pinion, and the re-action to this power is given by ſome machinery which the teeth of the large wheel actuates. In this caſe the drift on the centre of the pinion will be very conſiderable, becauſe the power is applied near the centre of the axis; but the wheel tranſmitting the power at a greater radius, will, perhaps, have much leſs drift on its centre (the proportion depending in ſome degree upon the direction in which the power and re-action are applied, as ſtated in our laſt obſervation): if this is the caſe, the gudgeon at that end of the ſhaft, where the pinion is placed, ſhould be lengthened out, ſo as to give the bearing point at a greater diſtance from it than the wheel, which ſhould have its gudgeon placed much nearer to it, becauſe leſs ſtrain is to be borne. By this means the drift upon the two ends of the ſhaft will be equally divided between them: and though this proportion of the centre cannot be always accompliſhed without inconvenience, the engineer ſhould always have it in view; and then, where it is not practicable, he ſhould attain the ſame end, by apportioning the ſtrength or diameter of the gudgeons to the relative ſtrains they have to bear.

An endleſs belt or ſtrap is a very general method of tranſmitting rotatory motion: it is uſually employed in caſes where a very quick motion is to be created, and the re-action to be overcome is nearly equable. In ſuch caſes it has the advantage of wheel-work from its ſimplicity and the eaſe of its motion. Some curious properties belong to the endleſs ſtrap, *viz* that the pulley or rigger it works upon muſt be largeſt in the middle, that is, the diameter muſt be greater in the middle of the pulley than at the edges, becauſe the ſtrap always rides on to the largeſt diameter of the pulley, and if this is not in the centre it will ſlip off at one ſide. It is not eaſy to give any ſatisfactory explanation of this fact, nor of another, that if, by accident, one of the pullies is ſtopped while the ſtrap is urged round by the motion of the other, it inſtantly flies off its pulley, unleſs the edge of the pulley ſhould be much wider than the ſtrap. This property is a great recommendation of it for ſome purpoſes, ſuch as threſhing mills, flour-dreſſing machines, lathes, cotton machines, &c. where any thing accidentally ſtopping the machines would deſtroy them if driven by wheel-work, but the ſtrap ſlips round, and very ſoon comes off, ſo as to avoid all further danger. Belts of *girt-web*, ſuch as are uſed for ſaddle girts, are ſometimes uſed inſtead of leather ſtraps, though theſe are undoubtedly preferable. The ſtrap ſhould be dreſſed to an equal thickneſs and breadth throughout, and the ends very neatly joined; that is, of the ſame thickneſs there as at every other part. It is ſometimes done by ſewing, but the beſt method is by gluing them together, with a glue compounded of Iriſh glue, iſinglaſs, ale grounds, and boiled linſeed oil. The two ends being tapered away and

overlapped are united with this cement, and will be as flexible as any other part, but ſo ſtrong that it will tear to pieces in any part rather than at the joint. A tool for equalizing the thickneſs and breadth of the ſtraps for belts is deſcribed in the Tranſactions of the Society of Arts, vol. xxviii. p. 192, invented by Mr Aubrey. They will by this means be rendered very correct, for nothing can be more unpleaſant in machinery than the joint and thick places in the endleſs ſtraps jerking over the riggers, and cauſing a violent drift upon the centres every time by the increaſed tenſion of the ſtrap.

A mechanic, in calculating any extenſive piece of machinery which is to depend upon ſtraps for the communication of its motions, particularly if they are of great length to convey their motion to a conſiderable diſtance, and have much ſtrain upon them, ſhould always conſider that ſuch machinery will loſe ſome of its velocity; that the wheels, which are turned by ſtraps, will never make quite ſo many revolutions as they ought to do from a calculation of their diameters. This is generally ſuppoſed to ariſe from the ſtrap ſlipping, in ſome degree, upon the ſurface of the wheels it paſſes over, but we are inclined to ſuſpect that it ariſes from another cauſe which has not been inveſtigated, *viz.* the elaſticity of the ſtrap: for inſtance, ſuppoſe that the diſtance between two wheels connected by a ſtrap is ten feet, and that the ſtrain upon the ſtrap is ſuch as to ſtretch or extend it two inches in that length on the ſide which bears the ſtrain (called by mechanics the leading ſide), on the other, or returning ſide, there will be no ſtrain, and therefore the ſtrap will return to its original length. In ſuch a caſe the wheel which is driven will loſe in its motion two inches in every ten feet, becauſe the ſtrap gives out that quantity in leading to the wheel, but takes it up again in returning, as ſoon as the ſtrain is removed from it.

Small machines are ſometimes turned by a catgut band, the ends of which are united by a ſmall ſteel hook and eye, the hook being faſtened at one end and the eyes at the other. They are made with tubes, for the reception of the ends of the band, which are tapped with a ſcrew withinſide, and the band being tapered and ſcrewed into the tube holds very faſt. But to prevent it drawing out, a ſmall quantity of roſin ſhould be applied to the end of the band which projects through the tube, and a hot wire being touched to it ſinges and hardens the end, that it will never draw out of the tube. This method is conſtantly uſed in ſmall lathes, and works very neatly. The pullies for a catgut-band ſhould always be cut with a ſharp angular groove, for the reception of the band, and it ſhould not touch the bottom of it, or it will be liable to ſlip. For the ſame reaſon, the pullies are beſt made of wood, becauſe metals ſoon acquire a poliſh, which prevent the band holding firmly upon it. The wood ſhould be cut with its grain acroſs the direction of the band, that every part of the circumference may be of a ſimilar texture.

Endleſs chains are ſometimes uſed to communicate motion of wheels, and frequently cogs are formed on the wheels to be received into the links of the chains. This method is very practicable on particular occaſions, and though it has not advantages to put it in competition with cog-wheels acting upon each other when they can be applied, it is in many inſtances a valuable reſource to the engineer to convey motion to ſome diſtance when it requires to be accurate, and where it would injure the operation of the machine if any motion was loſt by the ſlipping of bands. In making ſuch chains the greateſt care is neceſſary to have all the links preciſely of one length, and the cogs very accurately fitted to them, or a great friction will be cauſed by the cogs forcing themſelves into ſpaces not exactly ſituated to receive them. The beſt way is to make the links in the manner of watch or clock chains, with iron plates, and holes drilled through them at equal diſtances, to receive croſs pins upon which the cogs are to act. By this means the lengths may be made far more accurately than by bending the iron in the manner of common chain links.

Mr. Nicholſon has deſcribed a ſpinning-wheel for children, at a charity-ſchool, in which a large horizontal wheel, with a ſlip of buff leather glued on its upper ſurface near the outer edge, drove twelve ſpindles, at which the ſame number of children ſat.

The ſpindles had each a ſmall roller, likewiſe faced with leather, and were capable, by an eaſy and inſtantaneous motion, of being thrown in contact with the large wheel at pleaſure; each child, therefore, could throw her own part of the apparatus into work, or cauſe it to ſtop as often or as long as ſhe pleaſed.

The winding bobbins for yarn at the cotton mills operate on the ſame ſimple and elegant principles, which poſſeſſes the advantages of drawing the thread with an equal velocity, whatever may be the quantity of the bobbins, and cannot break it. The ſame mode of communication has been adopted in large work by Mr. Taylor, of Southampton, in his ſaw mills. In this the wheels acted upon each other by the contact of the end grain of wood inſtead of cogs. The whole made very little noiſe and wore very well: it was in uſe nearly twenty years. There is of conſequence a contrivance to make the wheels bear firm againſt each other, either by wedges at the ſocket or by levers. This principle and method of tranſmitting mechanic power certainly deſerve attention; particularly as the cuſtomary mode by means of teeth requires much ſkill and care in the execution; and after all wants frequent repair. We have ſeen it applied to a threſhing machine, a ſmall wheel on the threſhing drum being applied in contact with the large wheel which gave motion to it, and a preſſure ſufficient to make it turn the machine was given by loading the ſocket for the ſpindle of the drum with a conſiderable weight. The ſame principle is capable of communicating motion with great accuracy when no force is required, as will be ſeen on a peruſal of Mr. Troughton's ingenious method of dividing aſtronomical inſtruments. See GRADUATION.

The conſtruction of bearings, pivots, gudgeons, or centres, of ſpindles, as they are indifferently termed, is a moſt important point; theſe parts being the principal ſeats of that friction which is the deſtruction of all machinery. Pivots are always made of iron or ſteel, both becauſe theſe ſubſtances are better adapted for rubbing ſurfaces, and that their ſtrength admits the pivot being as ſmall as poſſible; the bearing, or bed to receive the gudgeons or pivots, ſhould be of a ſofter metal, as braſs, tin, or zinc, and kept well ſupplied with oil when at work. Hardened ſteel is a moſt admirable ſubſtance for pivots, which have a great ſtrain to bear, and a rapid motion. The bearing or bed may alſo be made of the ſame material, and is the only inſtance where two bodies, having friction againſt each other, can with propriety be made of the ſame ſubſtance: for it is found, that where iron or ſoft ſteel ſurfaces are worked with a friction againſt parts of the ſame ſubſtance, the friction and abraſion are far greater than when a ſofter material, as braſs, tin, hard wood, ivory, horn, &c. is uſed. The great difficulty of making hard ſteel pivots to ſpindles is the only reaſon they are not generally uſed; but there are ſome caſes, in which nothing elſe can be employed: where ſteadineſs and accuracy of motion are required, and great velocity at the ſame time. To obtain this accuracy, it is neceſſary that the

pivot ſhould be fitted, and kept in accurate contact with the interior ſurface of its ſocket or pivot-hole, and this will preſent a ſufficient acceſs of oil, to prevent any other ſpindle, than one of hardened ſteel, from burning or heating by the friction, when in rapid motion; and the expanſion occaſioned by this heat increaſes the preſſure and the friction, till the pivot becomes fixed in its ſocket, and will rather twiſt off than turn round in it. The ſpindle for a turning lathe muſt always be of hard ſteel; and even then, a failure of the ſupply of oil for a moment, will cauſe it to burn into the collar. Circular ſaw-ſpindles are frequently burnt in the ſame manner; their motion being very quick.

The beſt form of a gudgeon or pivot for a ſpindle, is that of a cylinder, with a flat ſhoulder, to prevent it from ſhifting its poſition endways. This form will bear moſt fairly and ſteadily; but it is neceſſary that the ſocket, or braſs which contains the pivot, ſhould be made in two halves, and put together with ſcrews, that the halves may be ſcrewed cloſer as the ſocket enlarges by wearing: but as this is only an imperfect method, becauſe the pivot can never fit accurately after having been worn, a conical form is uſed for the pivots of axles requiring great accuracy, as theſe may be always made to fill their ſockets, by preſſing the cone farther into its ſocket. The cone is uſed in many turning lathes, whilſt others are made very nearly cylindrical, with a ſhoulder; and as the collar is of hard ſteel, they do not wear in any ſenſible degree. Their advantage over the cone is, that they have no drift endways upon the oppoſite centre, as the cone has; though this is ſo ſlight in an acute cone, as to be of no importance in ſmall machinery. In heavy works, ſuch as the gudgeons of water-wheels, a conical figure would be highly improper, and has no advantage to recommend it; as ſuch gudgeons ſeldom have any braſs ſcrewed down over them, their own weight being ſufficient to keep them down, and they always fit true as they wear away. The moſt accurate and ſimple of all pivots is that which is ſimilar to a piece of work, while turning in a lathe; the axis having a ſmall hole made in each end of it, and the ſupports formed by ſharp conical points, received into the holes; and one of them muſt be adjuſtable by a ſcrew, to make it always fit the length of the ſpindle. It is uſual to make the conical points on the ends of two ſcrews, either of which may then be adjuſted. The ſame thing may be accompliſhed by making conical points at the ends of the ſpindle, and forming the holes for its reception in ends of the two fixed ſcrews, which can at all times be ſcrewed up as the parts wear. It is the moſt perfect of all methods, but is not adapted to bear any great ſtrain, becauſe the ſcrews will get looſe, and all the objections to the conical ſpindle apply to it.

The pivot at the lower end of a vertical ſhaft, which has a great weight to ſuſtain, as in a heavy horſe-wheel, is very properly made of a hemiſpherical figure, and received into a proper cavity. A cylindrical pivot, having a flat end, is frequently uſed for large and heavy upright axes; but it is difficult to keep oil ſupplied to them, as the great weight preſſes it out from between the acting ſurfaces, and the gudgeon burns. To avoid this, ſome mechanics make a cleft acroſs the lower face of the gudgeon, exactly in the manner of a ſcrew-head. This getting full of oil, is conſtantly ſupplied to the acting ſurfaces.

We have ſeen an horizontal windmill, having a vertical axis 100 feet high, with ſails and wheels of immenſe weight, all bearing upon one pivot. This was with the greateſt difficulty kept in order; and it was neceſſary to keep a ſmall ſtream of cold water always running into a pan, which ſurrounded the gudgeon, to keep it cold. This method of watering, inſtead of oiling, a gudgeon is alſo uſed in paper-mills; but it cannot be recommended as a good method.

Friction-rollers are frequently uſed for ſupporting gudgeons, and, if made with great care, have the leaſt friction which can be conceived; but they are liable to get out of order, if not made with extreme accuracy. See MILL-*Work*.

A great number of machines depend upon reciprocating motions, ſuch as pump-mills, ſaw-mills, &c. Where the firſt mover has a circular motion, as a water-wheel, the reciprocating movement will be moſt conveniently produced by means of a crank; becauſe it commences the change of motion by degrees, and does not ſuddenly urge the parts into motion in a contrary direction; nor ſuddenly check the movement again, but effects both changes without violence. It is proper, in ſuch caſes, to regulate the motion of the firſt mover by a fly-wheel, otherwiſe the reſiſtance of the work, at the inſtant of the change of motion, is ſo ſmall, that the machine would accelerate in that period, and then be checked again. The ſame may be accompliſhed by having ſeveral of the reciprocating movements and theſe act alternately, that when one requires the moſt power, the others take the leaſt, ſo as to equalize the reſiſtance to the firſt mover, and make the motion uniform. All reciprocating machines labour under great diſadvantages, from the circumſtance that a great maſs of matter muſt be put in motion, and this motion deſtroyed again. Thus, in a ſingle pump forcing water through a great height of pipes, the column of water is, at every ſtroke the pump makes, put in rapid motion, which is wholly loſt during the return of the pump-bucket for another ſtroke, when freſh impetus muſt be given to the water: now by applying a double acting pump, or two or three pumps acting at intervals, and the water regulated by an air-veſſel, the motion will be very eaſy, becauſe the column of water will be in conſtant motion through the pipes, and the momentum once given to it will continue as long as the machine is at work, inſtead of requiring a repetition of it at every ſtroke.

In every machine, the action of the moving power is transferred to the working point, through the parts of the machinery, which are material, inert, and heavy; or, to deſcribe it more accurately, before the neceſſary force can be excited at the working point of the machine, the various connecting forces muſt be exerted in the different parts of the machine: and in order that the working point may follow out the impreſſion already made, all the connecting parts or limbs of the machine muſt be moved in different directions, and with different velocities. Force is neceſſary for thus changing the ſtate of all this matter, and frequently a very conſiderable force. Time muſt alſo elapſe before all this can be accompliſhed. This often conſumes, and really waſtes, a great part of the impelling power. Thus, in a crane worked by men walking in a wheel, it acquires motion by ſlow degrees; becauſe, in order to give ſufficient room for the action of the number of men or cattle that are neceſſary, a very capacious wheel muſt be employed, containing a great quantity of inert matter. All of this muſt be put in motion by a very moderate preponderance of the men: it accelerates ſlowly, and the load is raiſed. When it has attained the required height, all this matter, now in conſiderable motion, muſt be ſtopped. This cannot be done in an inſtant, with a jolt, which would be very inconvenient, and even hurtful: it is therefore brought to reſt gradually. This alſo conſumes time. Nay, the wheel muſt get a motion in the contrary direction, that the load may be lowered into the cart or lighter; and this can only be accompliſhed by degrees. Then the tackle muſt be lowered down again

for another load, which alſo muſt be done gradually. All this waſtes a great deal both of time and force, and renders a walking-wheel a very improper form for the firſt mover of a crane, or any machine whoſe uſe requires ſuch frequent changes of motion. The ſame thing obtains, although in a lower degree, in the ſteam-engine, where the great beam and pump-rods, ſometimes weighing many tons, muſt be made to acquire a very briſk motion in oppoſite directions, twice in every working ſtroke. It operates in a greater or a leſs degree, in all engines which have a reciprocating motion in any of their parts. Pump-mills are of neceſſity ſubjected to this inconvenience. In the famous engine at Marly, about $\frac{19}{2}$ths of the whole moving power of ſome of the water-wheels is employed in giving a reciprocating motion to a ſet of rods and chains, which extend from the wheels to a ciſtern about three-fourths of a mile diſtant, where they work a ſet of pumps: thus the engine is, by ſuch injudicious conſtruction, a monument of magnificence, and the ſtruggle of ignorance with the unchangeable laws of nature. In machines, all the parts of which continue the direction of their motion unchanged, the inertia of a great maſs of matter does no harm; but, on the contrary, contributes to preſerve the ſteadineſs of the motion, in ſpite of ſmall inequalities of power or reſiſtance, or unavoidable irregularities of force in the interior part. But in all reciprocations, it is highly prejudicial to the performance; and, therefore, conſtructions which admit ſuch reciprocation without neceſſity, are avoided by all the intelligent engineers.

In many machines, but generally in ſmall works, what are called hearts, camms, ſnails, excentric wheels, &c. are a very excellent method of producing ſlight reciprocating movements to levers. From the rotatory motion of an axis, they have the great advantage of admitting any modification of the motion, to act ſuddenly or gradually, in either direction, at the pleaſure of the maker. This is done, by wheels of a particular form, faſtened upon an axis, and levers applied in contact with their circumferences, which receive a motion in proportion as the different radii of the wheels alter their lengths; and if, at any point of the motion, the lever is to be in a ſtate of reſt, the periphery of the wheel is, during that period, made a circular arc, and concentric with the axis. From the facility of producing any motion whatever by camms, it is an univerſal method, and applicable to all ſubjects; but ſtill has objections, which will induce the engineer to neglect it in thoſe inſtances, where any other movement will anſwer the ſame purpoſe. Theſe objections are the great friction, and wear of the camms, which ſoon unfits them for accurate motion: this may in ſome meaſure be obviated by applying rollers in the ends of the levers, to receive the contact of the camm. Another objection is, that the camm is unfit for producing a double motion, becauſe a ſpring or weight muſt be introduced to return the lever, and always keep it in contact with the camm. Now if this ſpring is only uſed to return the lever, it will operate very well; but if it is made ſo ſtrong as to effect any operation of the machine, the friction will be great, and be a ſerious objection to the uſe of camms.

The principles of theſe movements, and practical directions for conſtructing camms for any kind of movement, is fully explained in our article DIAGONAL *Motion*, which renders it unneceſſary to enlarge upon the ſubject in this place. Camms are uſed on a large ſcale in rolling-mills, for working the ſhears with which large iron bars are clipped into lengths. They are alſo employed in the machine for punching holes through the iron plates for boilers, weaving machines, &c.; and are in common uſe in the blowing machine uſed in iron forges; but it is a very injudicious application, and a common crank would be much better.

We once with great pleaſure contemplated a very complicated machine, in which were many reciprocating parts neceſſarily operating only whilſt moving in one direction; in the other, they had merely to return to repeat their operations. To produce this reciprocation, the inventor applied a crank, which was cauſed to revolve by the action of a pair of elliptical cog-wheels, each balanced on an axis paſſing through one of its foci. In this conſtruction, the motion of the driven wheel and the crank it carried, was exceedingly variable, but by equal increments of alternate acceleration and retardation. Thus when the long radius of the firſt wheel was operating, it met the ſhorteſt radius of the other, therefore giving it and alſo the crank a rapid motion: in this ſtate, the crank was returning to repeat its ſtroke, and with a quick ſtroke; but by the time it had completed half a revolution, the action was reverſed, the ſhort radius of the firſt wheel acting upon the long radius of the ſecond, which was therefore with its crank at the ſloweſt point of its movement: but the decreaſe of the motion, from the quickeſt to the ſloweſt point of its revolution, being effected by equal increments, gave no ſhock to the machinery. The crank was of courſe, during the ſlow half of its movement, performing its work; and in the quick period, returning to fetch its ſtroke. By this judicious arrangement, the reſiſtance to the firſt movement was very nearly equable: for when it had work to perform, the wheel-work gained a power upon the working point; but in returning, it cauſed it to urge the working point with ſuch an increaſed velocity, as in ſome degree counterbalanced the diminiſhed reſiſtance: but in this, no loſs was occaſioned, becauſe this increaſed velocity ſhortened the period of inaction haſtening the return to a ſituation for repeating its operation.

Theſe elliptical wheels are, in the hands of an able mechanic, a very uſeful contrivance, but they have not been much uſed in machinery, from the difficulties of forming their teeth with preciſion. In the COMETARIUM, (ſee that article,) they are introduced to repreſent the elliptic motions of comets, and we have ſeen two inſtances of their being uſed in large machines, where they operated with as much facility as circular wheels. It is to be obſerved, that a ſmall excentricity of the ellipſe, conſequently a ſlight deviation from the circular figure, will produce a great inequality of their motion, becauſe the increaſe of the acting radius of one wheel, is attended with a correſpondent decreaſe of the other, ſo that to produce almoſt any differences of motion which can be required in practice, the excentricity of the wheels will be ſuch as can eaſily be accompliſhed, and as will work with each other ſmoothly and accurately. When heavy ſtampers are to be raiſed in order to drop on the matter to be pounded, the wipers, by which they are lifted, ſhould be made of ſuch a form that the ſtamper may be raiſed by an uniform preſſure, or with a motion almoſt imperceptible at firſt. If this is not attended to, and the wiper is only a pin ſticking out from the axis, the ſtamper is forced into motion at once. This occaſions a violent jolt to the machine, and great ſtrains on its moving parts and their points of ſupport: whereas, when they are gradually lifted at firſt, the inequality of deſultory motion is never felt at the impelled point of the machine.

We have ſeen piſtons of pumps moved by means of a double rack on the piſton rod: a half wheel takes hold of one rack and raiſes it to the required height. The moment the half wheel has quitted that ſide of the rack, it lays hold of the other ſide and forces the piſton down again. This has been propoſed as a great improvement, by correcting

the unequable motion of the piſton, moved in the common way by a crank motion; but it occaſions ſuch abrupt changes of motion, that the machine is ſhaken by jolts. Indeed, if the movements were accurately executed, the machine would be ſoon ſhaken to pieces, if the parts did not give way by bending and yielding. Accordingly we have always obſerved that this motion ſoon failed, and was changed for one that was more ſmooth: a judicious engineer will avoid all ſuch ſudden changes of motion, eſpecially in any ponderous part of a machine.

When ſeveral ſtampers, piſtons, or other reciprocal movers are to be raiſed and depreſſed, common ſenſe teaches us to diſtribute their times of action in an uniform manner, ſo that the machine may always be equally loaded with work. When this is done, and the obſervations in the preceding paragraph attended to, the machine may be made to move, almoſt as ſmoothly as if there were no reciprocations in it. Nothing ſhews the ingenuity of the engineer more, than the artful, yet ſimple and effectual contrivances, for obviating thoſe difficulties that unavoidably ariſe from the very nature of the work to be performed by the machine, or in the power employed to actuate it.

In the contrivance of machinery, an engineer muſt not be tied down by too many inviolable maxims, becauſe thoſe contrivances which are the moſt improper in ſome ſituations will be the beſt of all in other caſes. There is great room for ingenuity and good judgment in the management of the moving power, when it is ſuch as cannot immediately produce the kind of motion required for effecting the purpoſe. We mentioned the converſion of the continued rotation of an axis into the reciprocating motion of a piſton, and the improvement which was thought to have been made on the common and obvious contrivance of a crank, by ſubſtituting a double rack on the piſton rod, and the inconvenience ariſing from the jolts occaſioned by this change. We have been informed of a great forge, where the engineer, in order to avoid the ſame inconvenience ariſing from the abrupt motion given to the great ſledge hammer of ſeven hundred weight, reſiſting with a five-fold momentum, formed the wipers for lifting it into ſpirals, which communicated motion to the hammer with ſcarcely any jolts whatever: but the reſult was, that the hammer roſe no higher than it had been raiſed in contact with the wiper, and then fell on the iron bloom, with very little effect. The cauſe of its inefficiency was not gueſſed at; but it was removed, and wipers of the common form were put in place of the ſpirals.

In this operation the rapid motion of the hammer is abſolutely neceſſary; it is not enough to lift it up, it muſt be raiſed up ſo as to fly higher than the wiper lifts it, and to ſtrike with great force the ſtrong oaken ſpring which is placed in its way. It compreſſes this ſpring, and is reflected by it with a conſiderable velocity, ſo as to hit the iron as if it had fallen from a great height: had it been allowed to fly to that height it would have fallen upon the iron with ſomewhat more force (becauſe no oaken ſpring is perfectly elaſtic); but this would have required more than twice the time.

In employing a power which of neceſſity reciprocates, to drive machinery which requires a continuous motion (as in applying the ſteam engine to a cotton or corn grinding mill), there alſo occur great difficulties. The neceſſity of reciprocation in the firſt mover waſtes much power, becauſe the inſtrument which communicates ſuch an enormous force muſt be extremely ſtrong, and be well ſupported. The impelling power is waſted in imparting, and afterwards deſtroying a vaſt quantity of motion in the working beam. The ſkilful engineer will attend to this, and do his utmoſt to procure the neceſſary ſtrength of this lever, without making it a vaſt load of inert matter. He will alſo remark, that all the ſtrains on it, and on its ſupports, are changing their directions in every ſtroke. This requires particular attention to the manner of ſupporting it: if we obſerve the old ſteam engines which have been long erected, we ſee that they have uniformly ſhaken the building to pieces. This has been owing to the ignorance or inattention of the engineer in this particular; they are much more judiciouſly erected now, experience having taught the moſt ignorant that no building can withſtand their deſultory and oppoſite jolts, and that the great movements muſt be ſupported by a frame work of wood or iron, independent of the building of maſonry which contains it. The gudgeons of a water wheel ſhould never reſt on the wall of the building; it ſhakes it, and if ſet to work ſoon after the building has been erected, it prevents the mortar from taking firm bond, perhaps by ſhattering the calcareous cryſtals as they form.

When the engineer is obliged to reſt the gudgeons in this way, they ſhould be ſupported by a block of oak laid a little hollow: this ſoftens all tremors, like the ſprings of a wheel carriage. This practice would be very ſerviceable in many other parts of the conſtruction. It will frequently conduce to the good performance of an engine, to make the action of the reſiſting work, unequable, and accommodated to the inequalities of the impelling power. This will produce a more uniform motion in machines, in which the momentum of inertia is inconſiderable. There are ſome beautiful ſpecimens of this kind of adjuſtment in the mechaniſm of animal bodies.

In many compound machines it is of conſequence to be able to detach part of the movements while the others continue in motion. Thus in cotton-ſpinning machines, it is neceſſary to be able to caſt off or ſtop any ſpindle at pleaſure, without diſturbing the reſt; and in a large mill containing many machines, it is eſſential that any one may be releaſed without interruption to the firſt mover. Such contrivances are called coupling or clutch-boxes: they are effected in various ways, ſome of which are detailed under COUPLING-BOX. But we wiſh here to deſcribe a recent improvement, very generally adopted in cotton and woollen mills; the object of which is to avoid a jerk being given to any machine when it is put in action, from its being ſuddenly urged from a ſtate of reſt to a ſtate of motion: for if the movement is to be rapid, nothing can be more deſtructive to the machine than the violence of the ſhock it receives from the common clutch-box. To avoid this, the arm which gives motion to the machine when the clutch of the running ſpindle is engaged with it, is not fixed faſt upon the ſpindle, but is made in two halves ſcrewed together upon a circular part of the ſpindle, and pinched upon it ſo faſt by the ſcrews, that it will have ſufficient friction to turn the machine round in the ordinary courſe of its work, but ſlips round upon the ſpindle, if the reſiſtance is greater than this friction, which thus becomes the meaſure of the power dealt out to the machine.

Suppoſe a machine of this kind at reſt, the clutch is turned by the firſt mover with a conſiderable velocity, and is ſuddenly connected with the arm above deſcribed: now it requires ſome time (independent of any reſiſtance or work of the machine) to put its parts in motion. In this time the arm ſlips round upon the ſpindle, but the friction acts conſtantly, and with an equable force upon the machine to turn it round. It commences its motion, which gradually accelerates, until it arrives at the ſame velocity as the driving ſpindle, and then the ſlipping of the box ceaſes, and the

machine proceeds in an uniform manner: ſtill the box is a very uſeful proviſion in caſe of any accident happening to the machine to ſtop it, by any thing getting into its movements: the box then ſlips round without breaking the works. All machinery, which is expoſed to the chance of great violence, ſhould be provided with ſome equivalent contrivance, which permits the movement to ſlip when the machine is overloaded and would otherwiſe be broken. An inſtance of this will be ſeen in the DREDGING *Engine*; ſee that article. The ſame effect may be produced by conical wheels fitting into each other, in the manner of a valve and its ſeat. One of them being fixed to each ſpindle, will, when they are jambed into each other, communicate the motion, but permits it to ſlip if overloaded. A very ingenious application of this will be found, in the mortiſing machine of the block machines at Portſmouth (ſee MACHINERY *for manufacturing Ships' Blocks*), and another judicious application of it under LOGWOOD *Mill*.

Many other contrivances are in uſe for detaching or uniting motions at pleaſure. In cog-wheels, the ſupports for the gudgeons are ſometimes fitted up ſo as to be moveable, that the wheels can be ſeparated to ſuch a diſtance as to relieve each other's teeth. At other times one of the wheels is fitted on a round part of its axis, and united with it at pleaſure by a clutch-box. Thus the wheels are always in motion, but one of them can be detached at pleaſure from its axis, on which it ſlips freely. Bevelled cog-wheels are eaſily diſengaged, by ſuffering the axis of one to move a little endways, and then their teeth are ſeparated.

Wheels turned by ſtraps are readily connected, or caſt off, by removing the ſtrap, but this is not eaſily done while the wheels are in motion; though ſome dextrous workmen are able to put on the ſtraps when the wheels are going; but it is attended with much difficulty, and great danger, if the motion is quick, of catching the fingers in the ſtrap. We have known an inſtance of a man's arm being torn away at the ſhoulder, by careleſſneſs in performing this operation.

For diſengaging the motion of a ſtrap, the contrivance called the live and dead pulley is very ingenious: it conſiſts of two pullies placed cloſe together upon any axis which is to receive a circular motion. The endleſs ſtrap or band, by encompaſſing one of theſe pullies, gives it a conſtant rotatory motion. Now one of them being fixed faſt upon the ſpindle, and the other ſlipping freely round upon it, gives the means of turning or diſcontinuing the motion of the ſpindle at pleaſure, by ſhifting the ſtrap either upon the live or dead pulley, which, as they are exactly of the ſame ſize, and cloſe to each other upon the ſpindle, is eaſily done. The live pulley is that which is fixed to its axis, ſo called from its cauſing life or motion to the ſpindle, and the machinery appended to it. The dead or idle pulley is that which ſlips upon its ſpindle; therefore, when the ſtrap is cauſed to run upon it, it turns round without giving any motion to the ſpindle. This contrivance is extremely well adapted to give motion to ſmall machinery, from the ſimplicity of its conſtruction, and the facility with which it is put in motion or at reſt. It poſſeſſes alſo another great advantage, *viz.* it occaſions no ſudden ſhock to the machinery at firſt ſtarting, as it does not inſtantly communicate to it the full velocity. To illuſtrate this, ſuppoſe the ſtrap running upon the dead pulley, and the machine therefore at reſt, the leading ſide of the ſtrap is in general conducted through a notch in a piece of board which is fitted in a groove, ſo as to have liberty of ſliding in ſuch a manner that it may conduct the ſtrap to work upon either of the pullies; but this is not neceſſary nor always attended to, for the perſon who attends the machine may, by the ſlighteſt preſſure on the leading ſide ſtrap by his hand, cauſe it to ſhift upon the other pulley; but as this is not done inſtantly, it communicates the motion to the live pulley by degrees; for at firſt ſhifting, it begins upon a very narrow ſurface of the pulley, which is, therefore, urged into motion, but without violence to the machine, as the ſtrap at firſt ſlips partially upon the ſurface of the live pulley, and this, as we have before ſtated, cauſes the ſtrap to endeavour to eſcape from the pulley; but the attendant continues to preſs the ſtrap on the leading ſide, and force it to act upon the live pulley, which having attained its full velocity, and the ſtrap no longer ſlipping upon it, has no tendency to get off, unleſs the machine is overloaded, and then it will get off to the dead pulley. The live and dead pulley is very extenſively uſed in cotton machinery, and is a very excellent contrivance; the only objection to it being that the buſh in the centre of the idle pulley is liable to wear very looſe in a ſhort time. It is ſcarcely neceſſary to add, that the driving wheel for the ſtrap of the live and dead pulley muſt be as broad on its edge as both the live and dead pulley together; indeed, it is generally a long cylindrical drum, which receives many ſtraps for turning different machines.

A motion is frequently required in machinery, by which a wheel or axis is made to revolve in one direction for any required time, and then at pleaſure changed, ſo as to revolve in the other direction. Various means may be uſed for effecting this purpoſe. The moſt common is by means of two equal and ſimilar bevelled or contrate wheels, ſituated on the ſame axis, and their teeth towards each other. A third bevelled wheel is applied with its axis perpendicular to the former, and its teeth engaging at pleaſure with either of the two wheels, which, as they turn the ſame way round, and can be made to act at one or other of the ſides of the third wheel, ſo as to turn it in either direction, as it is engaged with either of the two wheels. This movement was applied by Mr. Smeaton to a machine he invented for drawing coals from coal-pits. In this the third wheel was a trundle, and could be, by a lever, made to work in the teeth of either of the cog-wheels which were mounted upon the axis of a water-wheel, and thus turned the trundle either way at pleaſure, to draw up or let down the baſkets or corves, which were ſuſpended from a drum upon the axis of the trundle. Some mechanics have conſtructed the contrivance in a different manner, by fitting the two wheels upon a circular part of their ſpindle, and ſuffering them to turn round freely upon it. Their teeth are always engaged with the teeth of the third wheel, and, therefore, they are always revolving in oppoſite directions, and either can at pleaſure be connected with the axis by a ſliding clutch-box, but which is not long enough to engage both at once. The axis can, by this means, be made to revolve in the direction of either wheel at pleaſure, by ſliding the clutch-box towards that wheel.

We have ſeen a very ingenious application of the live and dead pulley to this purpoſe, for a crane in a cotton mill, to take up and down the goods, work-people, &c. It was invented by Mr. Henry Strutt, and has been applied in his cotton mills at Belper, Derbyſhire. In this machine it was neceſſary to have a motion which could be turned either way at pleaſure, to draw up or let down the baſket; but the double wheel-work above deſcribed was evidently improper, from the ſudden jerk it would have given at the inſtant of changing the motion. It was effected in this manner: an axis which gave motion to the crane barrel, has two pair of live and dead pullies upon it, and alſo a brake wheel to ſtop the motion, which is ſituated between the two pair: an endleſs ſtrap is conducted to each pair, being turned by a long drum placed parallel to the axis of the pullies, and kept in conſtant motion by the mill. One of theſe endleſs ſtraps is croſſed

between the drum and its pullies, but the other is not, therefore one pair of the live or dead pullies are always revolving in one direction, and the others are turning in an opposite way. Both straps are conducted through guides fixed to a sliding rail, by which the straps can be shifted both at once, sideways. When this rail is in a position that the straps are both upon their dead pullies, the axis and brake wheel are at rest, and in this position the rail has a tendency to remain, unless forced by hand. On moving the rail one way from the quiescent point, one of the straps is thrown on its live pulley, and the spindle turns with it, winding up the basket. By moving the rail in the other direction beyond its quiescent point, this strap is shifted on to its dead pulley, and becomes inactive; but the other strap operates on its live pulley, to turn the spindle in the opposite direction, and lets down the basket. We shall describe this very useful and curious machine in its place among the cotton machinery. See MANUFACTURE *of Cotton*.

Logwood rasping engines, screw presses, and some other machines, require a motion to work them forwards to a certain extent, and then the direction is to be reversed to draw them back, which requires but very little power to effect it. In this case the motion may be effected by a pair of cog-wheels turning each other, and thus communicating the motion for one direction in which it is to perform the work. A couple of pullies are fixed on the respective axes near the cog-wheels, and an endless strap connects them, but the strap is so long, that when the cog-wheels are in gear, the strap hangs slack, and does not operate: but to reverse the movement, the sockets for one of the gudgeons of the driving spindle or axis is made to shift, that the distance between the centre of the two wheels may be increased, so as to disengage the teeth of the wheels, and the strap becomes tight, and turns the wheels back; but on bringing the wheels together again, the strap becomes slack, and the wheels resume their original course.

Screws are, of all the mechanical powers, the most frequently used in machines, though not always as moving parts, being chiefly introduced for uniting and retaining the parts. They are not so constantly employed as acting movements, on account of their friction, and the trouble of making them; they are, nevertheless, a very useful agent on many occasions, and possess the advantage of accurately retaining any movement they make, and producing an extremely slow motion with ease, and, when it is required, with the most perfect accuracy. No engineer will employ screws for a rapid motion, as their friction and great wear renders them unfit for such situations. To the endless screw acting on the teeth of cog-wheels, this objection does not apply so forcibly, because the great number of teeth on which the screw operates successively, do not wear so fast as the nut of a female screw would under the same circumstances, and the friction is far less, because the screw is not enclosed all round its thread. The endless screw or worm is useful on many occasions to obtain a slow motion, which it does in a very simple manner; but, for the purpose of obtaining a quick motion, it should never be used, on account of the friction and consequent wear. This is seen in the common roasting jack.

In many situations in which moving screws are used, the same effects may be produced in the most simple and convenient manner by Mr. Bramah's method of producing and applying a more considerable degree of power to all kinds of machinery requiring motion and force, than by any means at present practised for the purpose This method, for which, on the 31st of March 1796, he obtained a patent, consists in the application of water, or other dense fluids, to various engines, so as, in some instances, to cause them to act with immense force; in others, to communicate the motion and powers of one part of a machine to some other part of the same machine; and lastly, to communicate the motion and force of one machine to another, though removed to a great distance from each other, and where their local situations preclude the application of all other methods of connection. The principle of this invention is the same with the hydrostatic paradox, but its various applications to useful purposes is due to Mr. Bramah. The simplest form is for a press, or machine, to raise an enormous weight to a small height: a metallic cylinder sufficiently strong, and bored perfectly smooth and cylindrical, has a solid piston fitted into it, which is made perfectly water tight, by leather packing round its edge, or other means used in hydraulic engines. The bottom of the cylinder must be made sufficiently strong, with the other parts of the surface, to resist the greatest strain which can ever be applied to it. In the bottom of the cylinder is inserted the end of a small tube, the aperture of which communicates with the inside of the cylinder, and introduces water or other fluids into it: the other end of the pipe communicates with a small forcing pump, by which the water can be injected into the cylinder under its piston: the pump has of course valves to prevent the return of the water. Now suppose the diameter of the cylinder to be twelve inches, and the diameter of the piston of the small pump or injector only one quarter of an inch, the proportion between the two surfaces or ends of the said pistons will be as 1 to 2304; and supposing the intermediate space between them to be filled with water, or other dense and incompressible fluids, any force applied to the small piston will operate upon the other in the above proportion, *viz.* as 1 to 2304. Suppose the small piston or injector to be forced down when in the act of forcing or injecting with a weight of 20 cwt. which can easily be done by means of a long lever, the piston of the great cylinder would then be moved up, with a force equal to 20 cwt. multiplied by 2304. Thus is constructed a hydro-mechanical engine, whereby a weight amounting to 2304 tons can be raised by a simple lever, in much less time through equal space, than could be done by any apparatus constructed on the known principles of mechanics, and it may be proper to observe, that the effect of all other mechanical combinations is counteracted by an accumulated complication of parts, which renders them incapable of being usefully extended beyond a certain degree, but in machines acted upon, or constructed on this principle, every difficulty of this kind is obviated, and their power subject to no finite restraint. To prove this, it will be only necessary to remark, that the force of any machine acting upon this principle can be increased, *ad infinitum*, either by extending the proportion between the diameter of the injector and the great cylinder, or by applying greater power to the lever actuating the small pump. On this principle very wonderful effects may be produced instantaneously, by means of compressed air. Suppose a large cylinder, furnished with a piston in the same manner as before described, a globular vessel is used, made of copper, iron, or other strong material, capable of resisting immense force, similar to those used for air guns: it has a strong tube of small bore, in which is a stop-cock: one of the ends of this tube communicates with the great cylinder beneath its piston, and the other end with the globe. Now suppose the great cylinder to be of the same diameter as that before described, and the small tube equal to one quarter of an inch diameter, which is the same as the injecting pump before-mentioned for the press: then suppose that air is injected into the globe (by the common methods) till it presses against the cock with a force equal to 20 cwt, which can be done; the consequence will be, that when the cock is opened, the piston will be instantly

moved in the great cylinder, with a power or force equal to 2304 tons, and it is obvious, as in the case before-mentioned, that any other unlimited degree of force may be acquired by machines or engines thus constructed. By the hydrostatic principle, the power and motion of any machine may be transferred or communicated to another, let their distance and local situation be what they may. Suppose two small tubes or cylinders, in the inside of each of which is a piston made water and air-tight, a tube may be conveyed under ground or otherwise, from the bottom of one cylinder to the other, to form a communication between them, notwithstanding their distance be ever so great. Let this tube be filled with water, or other fluid, until it touches the bottom of the two pistons; then, by depressing the piston of one cylinder, the piston of the other will be raised. The same effect will be produced, *vice versâ;* thus bells may be rung, wheels turned, or other machinery put invisibly in motion by a power being applied to either cylinder.

By these means, it is obvious, that most commodious machines of prodigious power, and susceptible of the greatest strength, may readily be formed. If the same multiplication of power be attempted by toothed-wheel pinions and racks, it is scarcely possible to give strength enough to the teeth of the racks, and the machines become very cumbersome, and of great expence. But Mr. Bramah's machine may be made abundantly strong in very small compass. It only requires very accurate execution. The hydrostatic principle on which it depends has been well known for nearly two centuries, and it is a matter of surprise that it has never before been applied to any useful practical purpose.

The application which Mr. Bramah has made of this truly valuable principle is very general: it was first applied for presses instead of large screws, for which purpose it is greatly superior in every respect. Presses being generally moved by the strength of men alone, the saving of power becomes a great object; and this it accomplishes, having no proportion of the friction of the screw, and immensely greater power. In a screw-press, it requires nearly as much labour to unscrew as to screw it up, an evidence of the enormous friction of a screw, when acting against a great pressure: but the hydrostatic-press only requires a cock to be opened to let out the water from beneath the piston, which then descends quickly, by its own gravity, or the elasticity of the substances under the pressure. But the greatest convenience of the hydrostatic principle is, that its power can so easily be transmitted to any distance, and in any direction, by means of pipes conducted along in situations where all other means of conveying the motion would be complicated, and expensive in the extreme. Thus, in a large paper-mill, an injecting-pump may be kept in constant action by the water-mill, or steam-engine, and inject water into an air-vessel, from which pipes are conducted to presses in all parts of the mill, and by simply opening a cock at any press, any required pressure will be instantly given by the elasticity of the confined air operating on the enlarged surface of the piston of any press. The air-vessel has, of course, a safety-valve, to allow the escape of the water when the pressure becomes so great as to endanger the rupture of any of the vessels; for it is to be observed, that the power of this principle is irresistible, when the pump is worked by a mill, and will burst any vessels, without the least appearance of strain on the moving parts of the pump.

In Mr. Bramah's extensive work-shops at Pimlico, and another at Mill-Bank, London, the steam-engines which turn the lathes, boring-machines, planing-machines, &c. work a small injecting-pump, as above-mentioned, and small copper pipes are laid to every part of the works, and by cocks admitting it into various cylinders, many powerful operations are performed: it works an immense press for bending strong iron bars, or breaking cast-iron for the foundery. It moves the carriage of the planing-engine; and he has brought the methods of packing the cylinders to such perfection, that they are employed to make the most delicate adjustments in the parts of the machine. (See a full description of this in PLANING *Engine*, and also PRESS, *Hydrostatic*.) In another part of the factory, it works a crane for lifting the heaviest goods, by merely opening a cock, and lowers them down, by opening another, with the utmost safety. A very large *Flood-gate* is also raised up by two cylinders. (See that article.) It may be used for turning the bridges of canals. (See CANAL.) On the whole, we cannot conclude this article, without recommending the hydrostatic principle very strongly to engineers, as a method the most perfect of all others of communicating motion, which is to act only for short extents, or with great power, as it can so easily be conducted through any circuitous rout, and loses so little power by friction. The ease with which it is relieved from the action, or caused to operate in a contrary direction, is not its smallest advantage; and by means of the air-vessel the power may be accumulated while the machine is preparing for action, and then an immense power suddenly given. We have little doubt the hydrostatic-press would answer the best of any method for expressing oil. The present oil-press is described under OIL-*Mill*, and operates by a wedge, driven by repeated blows of a heavy stamper. The method is ingenious; but great part of the power is expended in friction, as is evident from the wedge requiring nothing to retain it, as it is driven, the friction over-balancing all the re-action of the substances pressed.

A motion is very frequently required in machinery for giving to any piece of wheel-work an increased or diminished velocity at pleasure. The most complete of these are the EXPANDING *Riggers* (see that article); but many other means may be employed. Thus, on two parallel spindles, which are to turn each other, place a number of wheels, increasing in size by regular steps, the smallest wheel of one spindle being opposite to the largest of the other. The same endless strap will fit any pair of them, and give a great variety of powers and velocities: the same may be effected by having a number of cog-wheels; and, instead of a strap, using an intermediate cog-wheel, which can be applied to connect any pair of the wheels at pleasure. A very ingenious application of double cones is used in a cotton-machine, called the double-speeder. See MANUFACTURE *of Cotton*, also Mr. Braithwate's CRANE.

It is very customary to add what is called a fly to machines. This is a heavy disk or hoop, or other mass of matter, balanced on its axis, and so connected with the machinery, as to turn briskly round with it. This may be done with the view of rendering the motion of the whole more regular, notwithstanding unavoidable inequalities of the accelerating forces, or of the resistances occasioned by the work: it then becomes a regulator. Suppose the resistance to a machine extremely unequal, and the impelling power perfectly constant; as when a bucket-wheel is employed to work one pump; when the piston has ended its working-stroke, and while it is going down the barrel, the power of the wheel being scarcely opposed, it accelerates the whole machine, and the piston arrives at the bottom of the barrel with considerable velocity; but in the rising again, the wheel is opposed by the column of water now pressing on the piston: this immediately retards the wheel; and when the piston has reached the top of the barrel, all the acceleration is undone, and is to begin again. The motion of

fuch a machine is very hobbling; but the furplus of accelerating force, at the beginning of a returning ftroke, will not make fuch a change in the motion of the machine, if we connect the fly with it; for the accelerating momentum is a determinate quantity: therefore, if the radius of the fly be great, this momentum will be attained by communicating a fmall angular motion to the machine. The momentum of the fly is as the fquare of its radius, therefore it refifts acceleration in this proportion; and although the overplus of power generates the fame momentum of rotation in the whole machine as before, it makes but a fmall and imperceptible addition to its velocity. If the diameter of the fly be doubled, the augmentation of rotation will be reduced to one-fourth. Thus, by giving a rapid motion to a fmall quantity of matter, the great acceleration during the return-ftroke of the pifton is prevented. This acceleration continues, however, during the whole of the returning ftroke, and at the end of it the machine has acquired its greateft velocity. Now, the working ftroke begins, and the overplus of power is at an end. The machine accelerates no more; but if the power is juft in equilibrium with the refiftance, it keeps the velocity which it has acquired, and is ftill more accelerated during the next returning ftroke. But now, at the beginning of the fubfequent working-ftroke, there is an overplus of refiftance, and a retardation begins and continues during the whole rife of the pifton; but it is inconfiderable in comparifon of what it would have been without the fly: for the fly, retaining its acquired momentum, drags forwards the reft of the machine, aiding the impelling power of the water-wheel. It does this by all the communications taking into each other in the oppofite direction; the teeth of the intervening wheels are heard to drop from their former contact on one fide, to a contact on the other. By confidering this procefs with attention, we eafily perceive that in a few ftrokes the overplus of power, during the returning ftroke, comes to be fo adjufted to the efficiency, during the working ftroke, that the accelerations and retardations exactly deftroy each other, and every fucceeding ftroke is made with the fame velocity, and an equal number of ftrokes is made in every fucceeding minute. Thus the machine acquires a general uniformity with trifling periodical inequalities. It is plain, that by fufficiently enlarging either the diameter, or the weight of the fly, the irregularity of the motion may be rendered as fmall as we pleafe. It is much better to enlarge the diameter: this preferves the friction more moderate, and the pivots wear lefs. For thefe reafons, a fly is, in general, a confiderable improvement in machinery, by equalling many exertions that are naturally very irregular. Thus a man, working at a common windlafs, exerts a very irregular preffure on the winch. In two of his pofitions in each turn, he can exert a force of near feventy pounds without fatigue, but in others he cannot exert above twenty-five; nor muft he be loaded with much above this in general. But if a large fly be connected properly with the windlafs, he will act with equal eafe and fpeed againft thirty or even forty pounds.

If any permanent change fhould happen in the impelling power, or in the refiftance, the fly makes no obftacle to its production in its full effect on the machine, and it will be obferved to accelerate or retard uniformly, till a new general fpeed is acquired, exactly correfponding with this new power and refiftance. Many machines include in their conftruction movements which are equivalent with this intentional regulation, a flour-mill for example. There is another kind of regulating fly, confifting of wings whirled brifkly round till the refiftance of the air prevents any great acceleration. This is a very bad one for a working machine, for it produces its effect by really wafting a part of the moving power. Frequently it employs a very great and unknown part of it, and robs the proprietor of much work. It fhould never be introduced into any machine employed in manufactures, except in the inftance of letting down heavy weights, where a wafte or re-action to power is the object.

Some rare cafes occur where a very different regulator is required, when a certain determined velocity is found neceffary: in this cafe, the machine is furnifhed at its extreme mover with a conical pendulum, confifting of two heavy balls hanging by rods, which move in very nice and fteady joint at the top of a vertical axis. It is well known, that when this axis turns round, with an angular velocity fuited to the length of thofe pendulums, the time of a revolution is determined.

Thus, if the length of each pendulum be $39\frac{1}{5}$ inches, the axis will make a revolution in two feconds very nearly. If we attempt to force it more fwiftly round, the balls will recede a little from the axis, but it employs as long time for a revolution as before; and we cannot make it turn fwifter, unlefs the impelling power be increafed beyond all probability: in which cafe, the pendulum will fly out from the centre till the rods are horizontal, after which every increafe of power will accelerate the machine very fenfibly, as it then becomes a fimple fly. Watt and Boulton have applied this contrivance with great ingenuity to their fteam engines when they are employed for driving machinery for manufactures which have a very changeable refiftance, and where a certain fpeed cannot be much departed from without great inconvenience. They have connected this recefs of the balls from the axis (which gives immediate indication of an increafe of power, or a diminution, or refiftance,) with a cock, which admits the fteam to the working cylinder. The balls flying out caufe the cock to clofe a little, and diminifh the fupply of fteam, if the impelling power diminifhes the next moment, and the balls again approach the axis, and the rotation goes on as before, although there may have occurred a very great excefs or deficiency of power. The fame contrivance may be employed to raife or lower the feeding fluice of a water-mill employed to drive machinery. (See MILL.) Suppofe all refiftance removed from the working point of a machine furnifhed with a very large or heavy fly, immediately connected with the working point; when a fmall force is applied to the impelled point of this machine, motion will begin in the machine, and the fly begin to turn, continue to prefs uniformly, and the machine will accelerate. This may be continued till the fly has required a very rapid motion. If, at this moment, a refifting body be applied to the working point, it will be acted on with very great force; for the fly has now accumulated, in its circumference, a very great momentum.

If a body were expofed immediately to the action of this circumference it would be violently ftruck, much more will it be fo, if the body be expofed to the action of the working point, which perhaps makes one turn while the fly makes a hundred. It will exert a hundred times more force (very nearly) than at its own circumference. All the motion which has been accumulated in the fly, during the whole progrefs of its acceleration, is exerted in an inftant at the working point, multiplied by the momentum, which depends on the proportion of the parts of the machine. It is thus that the coining prefs performs its office; nay, it is thus that the blackfmith forges a bar of iron. Swinging the great fledge hammer round his head, and urging it with force the whole way, this accumulated motion is at once extinguifhed by impact on the iron. It is thus we drive a nail; and it is

thus, that by accumulating a very moderate force exerted during four or five turns of a fly, the whole of it is exerted on a punch, set on a thick plate of iron, such as is employed for the boilers of steam engines, and the plate is pierced as if it were a piece of cheese. This accumulating power of a fly has occasioned many, who think themselves engineers, to imagine, that a fly really adds power or mechanical force to an engine; and, not understanding on what its efficacy depends, they often place the fly in a situation where it only added a useless burden to the machine. If intended for a mere regulator, it should be near the first mover: if it is intended to accumulate force in the working point, it should not be far separated from it. In a certain sense, a fly may be said to add power to a machine, because by accumulating into the exertion of one moment the exertions of many, we can sometimes overcome an obstacle that we never could have balanced by the same machine unaided by the fly. See FLY-WHEEL.

It is this accumulation of force which gives such an appearance of power to some of our first movers. When a man is unfortunately catched by the teeth of a paltry country mill, he is crushed almost to mummy. The power of the stream is conceived to be prodigious, and yet we are certain, upon examination, that it amounts to the pressure of no more than fifty or sixty pounds; but this force has been acting for some time, and there is a millstone of a ton weight whirling twice round in a second. This is the force that crushed the unfortunate man; and it required it all to do it, for the mill stopped. We have been informed of a mill in the neighbourhood of Elbingroda, in Hanover, where there was a contrivance which disengaged the millstone when any thing got entangled in the teeth of the wheels. On being tried with a head of cabbage, it crushed it, but not violently, and would, by no means, have broken a man's arm.

It is hardly necessary to recommend simplicity in the construction of machines. This seems now sufficiently understood. Multiplicity of motions and communications increase friction; augment the unavoidable losses by bending and yielding in every part; expose all the imperfections of workmanship; and have a great chance of being indistinctly conceived; and are therefore constructions without science. We shall consider this object as applied to large machinery under MILL *Work*.

MACHINERY *for manufacturing Cotton*. See MANUFACTURE *of Cotton*.

Malt Liquors

MALT *Liquors* have different names as well as different virtues, properties, and uses, both from the different manners of preparing the malt, whence they are distinguished into *pale* and *brown;* and from the different manners of preparing or brewing the liquors themselves, whence they are divided into *beer* and *ale*, *strong* and *small*, *new* and *old*.

Malt drinks are either pale or brown, as the malt is more or less dried on the kiln; that which is the slenderest dried, tinging the liquor least in brewing, and therefore being called *pale:* whereas that higher dried, and as it were roasted, makes it of a higher colour. A mixture of both these makes an amber colour; whence several of these liquors take their name.

Now, it is certain, the pale malt has most of the natural grain in it, and is therefore the most nourishing; but for the same reason, it requires a stronger constitution to digest it. Those who drink much of it, are usually fat and sleek in their bloom, but are often cut off by sudden fevers; or, if they avoid this, they fall early into a distempered old age.

The brown malt makes a drink much less viscid, and fitter to pass the several strainers of the body; but, if very strong, it may lead on to the same inconveniences with the pale; though a single debauch wears off much more easily in the brown.

Dr. Quincy observes, that the best pale malt liquors are those brewed with hard waters, as those of springs and wells, because the mineral particles, with which these waters are impregnated, help to prevent the cohesions of those drawn from the grain, and enable them to pass the proper secretions the better; as the viscid particles of the grain do likewise defend these from doing the mischief they might otherwise occasion. But softer waters seem best suited to draw out the substances of high-dried malts, which retain many fiery particles in their contexture, and are therefore best lost in a smooth vehicle.

For the differences in the preparation of malt liquors, they chiefly consist in the use of hops, as in beer; or in the more sparing use of them, as in ale.

The difference made by hops is best discovered from the nature and quality of the hops themselves: these are known to be a subtle grateful bitter: in their composition, therefore, with this liquor, they add somewhat of an alkaline nature, *i. e.* particles that are sublime, active, and rigid. By which means, the ropy viscid parts of the malt are more divided and subtilized; and are, therefore, not only rendered more easy of digestion and secretion in the body, but also, while in the liquor, they prevent it from running into such cohesions as would make it ropy, vapid, and sour.

For want of this, in unhopped drinks, that clammy sweetness, which they retain after working, soon turns them acid, and unfit for use; which happens sooner or later, in proportion to the strength they receive from the malt, and the comminution they have undergone from fermentation.

It is a common opinion, that ale is more diuretic than beer, that is, liquor less hopped more than that with a greater quantity of hops in it: which may hold in some constitutions, because ale being more smooth, softening, and relaxing, where urine is to be promoted by enlarging the passage, as in thin, dry constitutions, this is the most likely to effect it. But where the promoting of urine is to be done by attenuating and breaking the juices, and rendering them more fluid, it is certainly best answered by those drinks which are well hopped.

As to the dispute, whether or no hops tend to breed the stone, it is too long to enter upon here. Quincy is of opinion, there is but little reason for the affirmative side of the question; and, in general, makes no scruple to say, that, for one constitution damaged by beer, there are numbers spoiled by ale. This last manifestly fouls the glands, stuffs the vessels with slime and viscidity, makes the body unwieldy and corpulent, and paves the way for cachexies, jaundice, asthmas, and at last incurable dropsies. The urinary passages, also, which it is supposed to clear, will, in time, be filled by it with slough, and matter of as ill consequence as gravel.

The different strengths of malt liquors also make their effects different. The stronger they are, the more viscid parts they carry into the blood; and though the spirituous parts make these imperceptible at first; yet when those are evaporated, which will be in a few hours, the other will be sensibly felt by pains in the head, nauseousness at the stomach, and lassitude or listlessness to motion. This, those are the most sensible of, who have experienced the extremes of drinking these liquors and wines; for a debauch of wine they find much sooner worn off, and they are much more lively and brisk afterwards, than after intemperately using malt liquors, whose viscid remains will be long before they be shaken off.

Malt liquors, therefore, are, in general, the more wholesome for being small, *i. e.* of such a strength as is liable to carry a small degree of warmth into the stomach, but not so great as to prevent their being proper diluters of the necessary food. Indeed, in robust people, or those who labour hard, the viscidities of the drink may be broken into a convenient nourishment; but in persons of another habit and way of living, they serve rather to promote obstructions and ill humours.

The age of malt liquors is the last thing by which they are rendered more or less wholesome. Age seems to do nearly the same thing as hops; for those liquors which are longest kept are certainly less viscid; age breaking the vis-

cid parts, and, by degrees, rendering them smaller, and fitter for secretion.

But this is always determined according to their strength; in proportion to which, they will sooner or later come to their full perfection, as well as decay; for, when ale or beer is kept till its particles are broken and comminuted as far as they are capable, then it is that they are best; and, beyond this, they will be continually on the decay, till the finer spirits are entirely escaped, and the remainder becomes vapid and sour.

MALT *Distillery*. This is an extensive article of trade, and by which very large fortunes are made. The art is to convert fermented malt liquors into a clear inflammable spirit, which may be either sold for use in the common state of a proof strength, that is, the same strength with French brandy; or is rectified into that purer spirit usually sold under the name of spirit of wine; or made into compound cordial waters, by being distilled again from herbs and other ingredients. See BREWING, SPIRITS, and WASH.

To brew with malt in the most advantageous manner, it is necessary, 1. That the subject be well prepared; 2. That the water be suitable and duly applied; and, 3. That some certain additions be used, or alterations made, according to the season of the year, and the intention of the operator; and by a proper regulation in these respects, all the fermentable parts of the subject will thus be brought into the tincture, and become fit for fermentation.

The due preparation of the subject consists in its being justly malted and well ground. When the grain is not sufficiently malted it is apt to prove hard, so that the water can have but very little power to dissolve its substance; and if it be much malted, a part of the fermentable matter is lost in that operation. The harder and more flinty the malt is, the finer it ought to be ground; and in all cases, when intended for distillation, it is advisable to reduce it to a kind of finer or coarser meal. When the malt is thus ground, it is found, by experience, that great part of the time, trouble, and expence of the brewing is saved by it, and yet as large a quantity of spirits will be produced; for thus the whole substance of the malt may remain mixed among the tincture and be fermented and distilled among it. This is a particular that very well deserves the attention of the malt distiller, as the trade is at present carried on; for the dispatch of the business, and the quantity of spirit procured, are more attended to than the purity or perfection of it.

The secret of this matter depends upon the thoroughly mixing, or briskly agitating and throwing the meal about, first in cold, and then in hot water; and repeating this agitation after the fermentation is over, when the thick turbid wash being immediately committed to the still, already hot and dewy with working, there is no danger of burning, unless by accident, even without the farther trouble of stirring, which in this case is found needless, though the quantity be ever so large, provided that requisite care and cleanliness be used; and thus the business of brewing and fermenting may very commodiously be performed together, and reduced to one single operation. Whatever water is made choice of, it must stand in a hot state upon the prepared malt, especially if a clear tincture be desired, but a known and very considerable inconvenience attends its being applied too hot, or too near to a state of boiling, or even scalding with regard to the hand. To save time in this case, and to prevent the malt running into lumps and clods, the best way is to put a certain measured quantity of cold water to the malt first; the malt is then to be stirred very well with this, so as to form a sort of thin uniform paste or pudding; after which the remaining quantity of water required may be added in a state of boiling, without the least danger of making what, in the distillers language, is called a pudding.

In this manner the due and necessary degree of heat in the water, for the extracting all the virtues of the malt, may be hit upon very expeditiously, and with a great deal of exactness, as the heat of boiling water is a fixed standard which may be let down to any degree by a proportionate mixture of cold water, due allowances being made for the season of the year, and for the temperature of the air.

This little obvious improvement, added to the method just above hinted for the reducing brewing and fermentation to one operation, will render it practicable to very considerable advantage, and the spirit improved in quality as well as quantity.

A much more profitable method than that usually practised for the fermenting malt for distillation, in order to get its spirit, is the following: Take ten pounds of malt reduced to a fine meal, and three pounds of common wheat-meal: add to these two gallons of cold water, and stir them well together, then add five gallons of water boiling hot, and stir all together again. Let the whole stand two hours, and then stir it again, and when grown cold, add to it two ounces of solid yeast, and set it by loosely covered in a warmish place, to ferment.

This is the Dutch method of preparing what they call the wash for malt spirit, whereby they save much trouble, and procure a large quantity of spirit: thus commodiously reducing the two businesses of brewing and fermenting to one single operation. In England the method is to draw and mash for spirit as they ordinarily do for beer, only instead of boiling the wort, they pump it into large coolers, and afterwards run it into their fermenting backs, to be there fermented with yeast. Thus they bestow twice as much labour as necessary, and lose a large quantity of their spirit by leaving the gross bottoms out of the still for fear of burning.

All simple spirits may be considered in their different states of low wines, proof spirit, and alcohol, the intermediate degrees of strength being of less general use; and they are to be judged of only according as they approach to, or recede from, these. Low wines, at a medium, contain a sixth part of pure inflammable spirit, five times as much water as spirit necessarily arising in the operation with a boiling heat. Proof goods contain about one-half of the same totally inflammable spirit; and alcohol entirely consists of it. See SPIRITS.

Malt low wines, prepared in the common way, are exceedingly nauseous; they have, however, a natural vinosity, or pungent agreeable acidity, which would render the spirit agreeable to the palate, were it not for the large quantity of the gross oil of the malt that abounds in it. When this oil is detained in some measure from mixing itself among the low wines, by the stretching a coarse flannel over the neck of the still, or at the orifice of the worm, the spirit becomes much purer in all respects; it is less fulsome to the taste, less offensive to the smell, and less milky to the eye. (Shaw's Essay on Distillery.) When these low wines, in the rectification into proof spirits, are distilled gently, they leave a considerable quantity of this gross fetid oil behind them in the still along with the phlegm; but if the fire be made fierce, this oil is again raised and brought over with the spirit; and being now broken somewhat more fine, it impregnates it in a more nauseous manner than at first. This is the common fault both of the malt distiller and

of the rectifier; the latter, instead of separating the spirit from this nasty oil, which is the principal intent of his process, attends only to the leaving the phlegm in such quantity behind, that the spirit may be of the due strength as proof or marketable goods, and brings over the oil in a worse state than before. To this inattention to the proper business of the process, it is owing that the spirit, after its several rectifications, as they are miscalled, is often found more stinking than when delivered out of the hands of the malt distiller. All this may be prevented by the taking more time in the subsequent distillations, and keeping the fire low and regular, the sudden stirring of the fire, and the hasty way of throwing on the fresh fuel, being the general occasions of throwing up the oil by spurts, where the fire in general, during the process, has not been so large as to do that mischief.

The use of a balneum Mariæ, instead of the common still, would effectually prevent all this mischief, and give a purer spirit in one rectification, than can otherwise be procured in ten, or indeed according to the common methods at all.

Malt low wine, when brought to the standard, or proof spirit, loses its milky colour, and is perfectly clear and bright, no more oil being contained in it than is perfectly dissolved by the alcohol, and rendered miscible with that proportion of phlegm, which is about one-half the liquor; its taste also is cleaner though not more pleasant; there being less of the thick oil to hang on the tongue in its own form, which is not the case in the low wines, where the oil, being undissolved, adheres to the mouth in its own form, and does not pass lightly over it.

When proof spirit of malt is distilled over again, in order to be rectified into alcohol, or, as we usually call it, spirits of wine, if the fire be raised at the time when the faints begin to come off, a very considerable quantity of oil will be raised by it, and will run in the visible form of oil from the nose of the worm. This is not peculiar to malt spirit, but the French brandy shews the same phenomenon, and that in so great a degree, that half an ounce of this oil may be obtained from a single piece of brandy.

Malt spirit, more than any other kind, requires to be brought into the form of alcohol, before it can be used internally, especially as it is now commonly made up in the proof state, with as much of this nauseous and viscous oil as will give it a good crown of bubbles. For this reason it ought to be reduced to an alcohol, or totally inflammable spirit, before it is admitted into any of the medicinal compositions. If it be used without this previous caution, the odious taste of the malt oil will be distinguished among all the other flavours of the ingredients.

Malt spirit, when it has once been reduced to the true form of an alcohol, is afterwards more fit for all the curious internal uses than even French brandy, it being after this purification a more uniform, hungry, tasteless and impregnable spirit, than any other spirits which we esteem so much finer.

A pure spirit being thus procured, should be kept carefully in vessels of glass or stone, well stopped to prevent the evaporation of any of its volatile part. If preserved in casks, it is apt to impregnate itself very strongly with the wood. The quantity of pure alcohol obtainable from a certain quantity of malt, differs according to the goodness of the subject, the manner of the operation, the season of the year, and the skilfulness of the workman; according to which variations, a quarter of malt will afford from eight or nine, to thirteen or fourteen gallons of alcohol. This should encourage the malt distiller to be careful and diligent in his business, as so very large a part of his profit depends wholly on the well conducting his processes.

After every operation in this business, there remains a quantity of faints, which in their own coarse state ought never to be admitted into the true spirit; these are to be saved together, and large quantities of them at once wrought into alcohol. It is easy to reduce these to such a state, that they will serve for lamp spirits. Their disagreeable flavour being corrected by the adding of aromatics during the distillations, the reducing them to a perfect and pure alcohol is practicable, but not without such difficulties, as render it scarcely worth the trader's while. One way of doing it is by distilling them from water into water, and that with a very slow fire. By this means a pure alcohol may be made out of the foulest faints.

The malt distiller always gives his spirit a single rectification *per se*, in order to purify it a little, and make it up proof, but in this state it is not reckoned fit for internal uses, but serves to be distilled into geneva and other ordinary compound strong waters for the vulgar.

The Dutch, who carry on a great trade with malt spirit, never give it any farther rectification than this, and it is on this account that the malt spirit of England is in general so much more in esteem. The Dutch method is only to distil the wash into low wines, and then to full proof spirit; they then directly make it into geneva, or else send it as it is to Germany, Guinea, and the East Indies, for the Dutch have little notion of our rectification. Their spirit is by this means rendered very foul and coarse, and is rendered yet more nauseous by the immoderate use they make of rye meal. Malt spirit, in its unrectified state, is usually found to have the common bubble proof, as the malt distiller knows that it will not be marketable without it.

The whole matter requisite to this is, that it have a considerable portion of the gross oil of the malt well broke and mixed along with it; this gives the rectifier a great deal of trouble if he will have the spirit fine; but in the general run of the business, the rectifier does not take out this oil, but breaks it finer, and mixes it faster in by alkaline salts, and disguises its taste by the addition of certain flavouring ingredients. The spirit loses in these processes the vinosity it had when it came out of the hands of the malt distiller, and is, in all respects, worse, except in the disguise of a mixed flavour. Shaw's Essay on Distillery.

The alkaline salts used by the rectifier, destroying the natural vinosity of the spirit, it is necessary to add an extraneous acid in order to give it a new one. The acid they generally use is the *spiritus nitri dulcis*; and the common way of using it is the mixing it to the taste with the rectified spirit: this gives our malt spirit, when well rectified, a flavour somewhat like that of French brandy, but this soon flies off; and the better method is to add a proper quantity of Glauber's strong spirit of nitre to the spirit in the still. The liquor in this case comes over impregnated with it, and the acid being more intimately mixed, the flavour is retained. See SPIRITUS *nitri dulcis*.

Manchester

MANCHESTER, a market town in the hundred of Salford and county of Lancafter, England, is feated on the banks of the fmall rivers Irk, Medlock, and Irwell, at the diftance of 185 miles from London and 32 from Liverpool. In point of commercial and political importance, though not a corporation, it is undoubtedly the fecond town in the kingdom. The whole population, according to the parliamentary cenfus of 1800, amounted to 84,053 perfons, of whom 44,500 were engaged in different branches of trade: 44,900 were females, and 39,110 were males. The amazing increafe of population in this town is fhewn by returns obtained in the years 1773 and 1811. In the former year there were 29,951 perfons; and in the latter 98,573. The parifh of Manchefter comprehends feveral of the contiguous townfhips, the whole population of which is 136,370.

Manchefter appears, from the teftimony of Mr. Whitaker, to be a town of great antiquity. A ftation occupied by the ancient Britons is fuppofed to have been fettled here 500 years before the Chriftian era. It did not, however, deferve the name of a town till after the invafion of this ifland by the Romans, when it became one of the fortified retreats of the brave but undifciplined natives. At this period it was called Mancenion, that is, the "place of tents;" but Agricola, who conquered it A.D. 79, changed its name to Mancunium. It was afterwards called Manduefuedum, and Mancaltre, from which latter term its prefent appellation is evidently derived. The Romans, upon achieving the conqueft of this ftation, built an extenfive caftle upon the fpot now denominated Caftle-field, fituated near the conflux of the Medlock with the Irwell; but every veftige of this is removed to make room for modern buildings. After having retained it in continued poffeffion for fomewhat more than 400 years, the declining fortunes of Rome compelled the legionary foldiers to abandon it to the original poffeffors, who in their turn foon yielded it to their new conquerors and tyrants the Saxons. During the dynafties of that ferocious people, Manchefter was feveral times a place of military conflict, being feated on the immediate confines of the Northumbrian kingdom. Edward the Elder, king of the Mercians, is faid to have fortified and rebuilt a confiderable part of it, which time and violence had united to deftroy. At the period of the grand Domefday furvey, two churches appear to have exifted here, called St. Mary's and St. Michael's. Albert de Grefley obtained from the Conqueror the lordfhip of the manor. In 1301 his grandfon, Thomas, granted a charter to his burgeffes of Manchefter, conftituting their town a free borough. Lord de la Warr, the laft male heir of this family, laid the foundation of the collegiate church, which tended, in no fmall degree, to promote its increafe and improvement. This town in early times was a place of fanctuary, and one of the eight places to which that privilege was confirmed by Henry VIII. in 1540. The year following, however, it was removed to Chefter, which the ftatute declares "had a ftrong gaol and a mayor, and had not the wealth, credit, great occupings and good order which Manchefter had." In 1605, a peftilence raged here, and carried off upwards of 1000 perfons. Upon the breaking out of the civil war between Charles I. and the parliament, Manchefter decidedly efpoufed the republican caufe, and fuccefsfully refifted feveral fieges by the royal army, under the earl of Derby. Notwithftanding thefe circumftances, however, the inhabitants feem to have honoured the reftoration of Charles II. with particular marks of joy.

From this fhort fketch it will readily be perceived that, in an hiftorical point of view, Manchefter is only entitled to a very fmall fhare of general attention: though regarded as a manufacturing town, it is defervedly diftinguifhed above every other in England. When it firft began to be noted for its manufactures is uncertain; but in the time of Edward VI. Manchefter cottons, Manchefter rugs, and Manchefter friezes are frequently mentioned in various acts of parliament. In 1650, its trade is defcribed as "not inferior to that of many cities in the kingdom, chiefly confifting in woollen friezes, fuftians, fack-cloths, mingled ftuffs, caps, inkles, tapes, points, &c. whereby not only the better fort of men are employed, but alfo the very children by their own labour can maintain themfelves. There are, befides, all kinds of foreign merchandize brought and returned by the merchants of the town, amounting to the fum of many thoufand pounds." About this time great quantities of linen yarn feem to have been imported here from Ireland, which being wrought into cloth, was refhipped for the Irifh market. It was not, however, till after the middle of the laft century, that Manchefter rofe to a pre-eminent rank among our manufacturing towns; a rank for which it is chiefly indebted to the ingenuity and invention of Mr. Hargreave and fir Richard Arkwright. Previous to the year 1760, all the cotton yarn manufactured in the country was fpun by hand, upon that well known domeftic inftrument

called a one-thread wheel. Shortly after this period, Mr. Hargreave conftructed a machine denominated a *jenny*, by which one perfon was enabled to fpin from twenty to forty threads at a time. Thefe machines foon came into general ufe, but were much limited in their employment till the year 1775, when fir Richard brought the improvements of his predeceffor to much greater perfection. This gentleman having eftablifhed his extenfive manufactories here, made Manchefter the principal feat of the fpinning trade, the rapid increafe of which produced a correfponding increafe in the buildings and population of the town. See the preceding articles of Arkwright, vol. ii. and Cotton, vol. x. for further particulars. In Brayley's "Beauties of England," vol. iii., Derbyfhire, is an interefting and ample memoir of fir Richard Arkwright, with accounts of the prefent ftate and proceffes of the cotton manufactures.

As Manchefter, notwithftanding its extent and political importance, is not a corporate town, the government is vefted in a headborough, called the boroughreeve, and two conftables. Thefe are chofen annually from the moft refpectable of the inhabitants by a jury impannelled by the fteward of the manor, at the courts leet, which are held by the lord of the manor twice every year at Eafter and Michaelmas. The boroughreeve is ufually one of the gentlemen who has ferved as conftable for the preceding year, and is treated perhaps with more refpect (the paraphernalia of a mace-bearer excepted), than any mayor in the kingdom. The chief duty of this officer is to prefide at public meetings, and to diftribute certain charities, denominated "boroughreeve charities," all the judicial functions connected with the police being executed by the conftables and their deputies. A court of requefts is held every month for the recovery of fmall debts; and every Wednefday and Saturday feveral refpectable magiftrates fit in the court-room of the New-Bayley for the adminiftration of juftice in pleas of almoft every defcription, whether civil or criminal. Quarter feffions alfo are held four times a-year; and, from prefs of bufinefs, the court is fometimes obliged to continue its fittings for nearly a fortnight.

This town is divided into two portions by the river Irwell, which receives the Irk at a fhort diftance from the collegiate church. The fituation of Salford is very fimilar to that of Southwark, the communication between the two towns being kept up, as in London, by three bridges thrown acrofs the river at different places. The moft ancient of thefe is called the "Hanging bridge," Old, or Salford bridge, and is fuppofed to have been originally founded in the time of the Romans. The prefent, built in the reign of Edward III., was formerly very dangerous for foot paffengers, but in 1778 it underwent a thorough repair and extenfion. Blackfriar's bridge, erected about fifty years ago, is conftructed entirely of wood, and flagged for foot paffengers only. But the fineft bridge over the Irwell is the New bridge, commonly called the New Bayley bridge, which was founded in 1785, and is conftructed wholly of ftone. It confifts of three large arches, and a fourth of fmaller dimenfions, left open in fupport of the duke of Bridgewater's right to a towing path to his quay, in Salford, agreeably to the tenor of the act, enabling His Grace to form his extenfive canals. Six bridges are here thrown acrofs the Irk, the chief of which are Huntfbank bridge, fituated near the college, and Scotland bridge: nine are thrown over the Medlock, which runs in a ferpentine courfe through the fouthern fuburbs of the town. Oxford-ftreet bridge forms a part of a ftreet of that name. A variety of other bridges lie acrofs the numerous canals which interfect the fuburbs at different places, and at Knotmill, in the vicinity of Caftle-field, is a very noble tunnel, through which the Rochdale canal paffes, not far from its junction with that of the late duke of Bridgewater's.

With refpect to the plan and buildings of this town, it may be remarked, that the portion of it called the Old Town confifts of a very motley affemblage of old and new houfes, clofely huddled together, and exhibiting little elegance in their exterior appearance. Even the new ftreets, though much fuperior to the old, are ufually narrow, except in a few inftances where they have been improved by the acts of 1775 and 1791. In thefe latter, however, there are a number of very excellent modern buildings. Mofley-ftreet and Portland place would do honour to the capital itfelf. Grofvenor-fquare, when finifhed, will probably rival the fineft in the kingdom. The fuburbs of Ardwick-green and Salford crefcent are peculiarly pleafant, and contain fome handfome houfes, which are moftly occupied by the wealthy manufacturers.

The churches and other public edifices of this town are numerous, but few of them are diftinguifhed for architectural beauty. The College, or parifh church, founded, as already mentioned, by lord de la Warr, bifhop of Durham and rector of Manchefter, is a venerable building in the rich ornamented ftye of the 15th century. In the interior its appearance is confufed and heterogeneous. The windows ftill retain many rich remains of the painted glafs with which they were formerly ornamented. The roof is of elegant wood-work, interfperfed with carved figures of angels playing upon different mufical inftruments. In front of the gallery, on each fide of the clock, are fufpended the colours of the 72d regiment, raifed in this town by fubfcription during the American war, whofe noble conduct at the fiege of Gibraltar is ftill remembered with exultation by every lover of his country, and particularly by the inhabitants of Manchefter. Adjoining to this church are a number of fmall chapels well worthy of the attention both of the architect and the antiquary. A view of this church, with a particular account of its hiftory and architectural peculiarities, written by J. H. Markland, F. S. A. are given in the third volume of "The Architectural Antiquities of Great Britain."

St. Ann's church, fituated at the end of the fquare to which it gives name, is diftinguifhed for its handfome appearance. It was founded by lady Ann Bland in 1709, in compliment to whom it was dedicated to the faint whofe name it bears. The church of St. Mary, fituated between Deanfgate and the river Irwell, is admired for the beauty and fine proportions of its fpire, which meafures 186 feet in height. The lanthorn which fupports it is peculiarly ftriking, being compofed of eight noble Ionic pillars, furmounted by a large globe, upon which is placed a maffy crofs. St. John's church is built in the ftyle which is called modern Gothic. In the veftry are feveral pictures, and a beautiful window of ftained glafs. Two of the windows in the body of the church are alfo decorated with fine painted glafs. The other churches in this town are St. Paul's in Turner-ftreet, St. James's in George-ftreet, St. Michael's in Angel-ftreet, St. Clement's in Lever-ftreet, St. Stephen's near Bolton-ftreet, St. George's in the neighbourhood of Newton-lane, and St. Peter's, which terminates the profpect down Dawfon-ftreet and Mofley-ftreet. The latter was defigned and executed by James Wyatt, efq. In Salford is Trinity chapel, a neat ftone edifice of the Doric order.

Befides thefe churches there are three others alfo belonging to the eftablifhment, fituated in the adjoining townfhips of Ardwick, Chorlton, and Pendleton, which, from their vicinity to Manchefter, may not improperly be confidered as belonging to it. Numerous chapels and meeting-houfes, appropriated for the public worfhip of diffenters of almoft every

denomination, are likewiſe diſperſed through various parts of the town. Catholics are numerous here, and the Methodiſts are found to comprise a very conſiderable proportion of the whole population.

The vaſt number of excellent charitable inſtitutions with which Mancheſter abounds are highly creditable to the benevolence, liberality, and public ſpirit of its inhabitants. Indeed, in this reſpect, this town is not ſurpaſſed by any in the Britiſh empire, whether the ſuitableneſs of the buildings for their reſpective purpoſes, or the liberal contributions by which they are ſupported, are taken into view. Among theſe eſtabliſhments, Chetham's-Hoſpital, commonly called the College, is firſt deſerving of notice, by priority of foundation. It owes its exiſtence and entire ſupport to the munificent bequeſt of Humphrey Chetham, eſq. of Clayton, whoſe will is dated the 16th of December 1651. At firſt, the number of boys clothed and educated here amounted only to forty; but from an increaſe in the value of the eſtates belonging to the foundation, the number was augmented more than thirty years ago to eighty. The building appropriated to this charity is ſituated on a lofty rock, near the confluence of the rivers Irk and Irwell, immediately adjoining to the collegiate church already mentioned, to which indeed it formerly belonged. Upon this ſpot Mr. Whitaker ſuppoſes the Romans had their prætorium, or ſummer camp; and certainly the ſituation was admirably adapted for that object. In a large gallery, in this edifice, is a public library, likewiſe founded by Mr. Chetham, which now contains upwards of 15,000 volumes in various languages, and in almoſt every branch of ſcience or literature, beſides ſome very valuable manuſcripts. The Infirmary, Diſpenſary, Lunatic Hoſpital, and Aſylum, are all included in one ſpacious building, ſituated in the front of Lever's Row, which is conſidered as the higheſt ground in the town. The foundation of the firſt edifice was laid in 1753, for the reception of forty patients; but the number was ſoon afterwards doubled, and now there are 160 beds appropriated for the uſe of the ſick. The Lunatic Hoſpital was opened in 1766, and the Diſpenſary in 1792. The annual ſubſcriptions for the ſupport of theſe inſtitutions, amount to ſeveral thouſand pounds. Here are two poor-houſes, one of which was erected in 1792, on the ſide of the Irk, nearly oppoſite the College; and the other built the year following, at the upper end of Greengate in Salford. Both of them are handſome buildings, and admirably fitted up for the purpoſe to which they are appropriated. The Lying-in-Hoſpital was inſtituted in 1790, and not only provides profeſſional aid for in-door patients, but likewiſe for the aſſiſtance of ſuch poor married women as find it inconvenient to leave their own houſes. The Houſe of Recovery is intended chiefly for the reception of patients afflicted with contagious fevers. The other principal charities are the ſtrangers-friend-ſociety, inſtituted in 1791, and the boroughreeve's charity: the former deſigned for the relief of ſtrangers, and the latter for the aid of the poor inhabitants in general. The Free-ſchool is an excellent foundation, which owes its origin to Hugh Oldham, biſhop of Exeter. In this ſchool the greater part of the clergy of the town and neighbourhood have been educated, as well as many noblemen. There are, beſides, ſeveral inferior charity and Sunday ſchools in various parts of Mancheſter.

Though in every reſpect a manufacturing town, Mancheſter has not wholly neglected the promotion of literature and ſcience. Societies, having this object in view, are numerous. The chief of them are the Literary and Philoſophical, inſtituted by Dr. Thomas Percival in 1781; and the Philological Society, which commenced its meetings in 1803. Here are alſo two very extenſive public circulating libraries; the former founded in 1757, and the latter in 1792. The Mancheſter Agricultural Society was eſtabliſhed in 1767, and has for its object the encouragement of the uſeful arts in general, by the diſtribution of premiums for ſcientific diſcoveries. A laudable practice is alſo adopted, of granting premiums to cottagers, who ſupport their families without parochial aid; and in ſome inſtances likewiſe, honeſt and good ſervants are rewarded by honorary preſents. The repoſitory, deſigned to encourage and reward induſtrious females, has proved highly ſerviceable to many individuals, and is therefore juſtly entitled to liberal and careful ſupport.

Beſides thoſe already noticed, many other public buildings and inſtitutions, intended either for uſeful purpoſes or for amuſement, may properly claim attention in this place. The Theatre, a commodious and extenſive building, was erected in 1807. It is open during ſeven months of the year, and can in general boaſt of a very reſpectable company of performers. The gentlemen's Concert-room is elegant and capacious, and will accommodate upwards of 1200 perſons. This is ſupported by a voluntary ſubſcription; and ſtrangers are admitted with a ſubſcriber's ticket. There are likewiſe very excellent new and commodious aſſembly-rooms for balls, card-aſſemblies, &c. The New-Bayley, or Penitentiary houſe, is well deſerving attention, both on account of the extent of the edifice and arrangement of its parts, and alſo for the economy obſerved in the interior. Immediately above the entrance is a large room, where the ſeſſions are held; and adjoining to it are ſeveral commodious rooms for the magiſtrates, jurors, &c. Beyond this, in the centre of a large area encloſed by lofty walls, ſtands the priſon, an extenſive building in the ſhape of a croſs, three ſtories high. It is remarkable for the cleanneſs with which it is kept, as well as for its regulations. Priſoners, not confined for capital crimes, are allowed the free exerciſe of their reſpective trades. A workhouſe, on a large ſcale, has alſo been lately built.

A new ſtructure, called the Mancheſter Commercial Building, or Exchange, was commenced in the year 1806, from deſigns by Mr. Harriſon, architect. It was completed in January 1809, and is appropriated to the uſe of the merchants and manufacturers of the town, who ſubſcribed certain ſhares of 50*l.* each, to defray the expences of its erection. The building compriſes an exchange-room, dining-room, drawing-room, ware-rooms, ſhops, and counting-houſes, a ſuite of rooms for the poſt-office, with extenſive cellars under the whole. It is built of ſtone, and preſents a ſimple, but claſſical façade, with demi-columns of the Grecian Doric order. The exchange-room is very ſpacious, containing an area of 4000 ſuperficial feet, in the centre of which is a glazed dome, 40 feet in height, ſupported by eight fluted columns of the Ionic order. Over a part of this room is a gallery, or ſemicircular ſuite of rooms, appropriated to an extenſive library, belonging to Mr. Ford, a reſpectable bookſeller of this town, whoſe large catalogue contains a valuable aſſortment of ſcarce, curious, and intereſting works.

The Trade of Mancheſter conſiſts chiefly, but not entirely, in the manufacture of cotton goods. Velverets, checks, a variety of ſmall articles, ſuch as filleting, tapes, laces, gartering, &c. are likewiſe made in great quantities. The ſilk manufacture has advanced rapidly here within the laſt ten years; and a manufactory for making and finiſhing hats is now carried on to a great extent. The profuſion of goods made here is conveyed, by means of the Irwell and the numerous canals which interſect the town, to different ports both on the eaſtern and weſtern coaſt. Liverpool, however, is the principal mart for the exportation of the cottons; and be-

tween that town and Manchefter there is a conftant and rapid communication both by land and water-carriage.

Manchefter has two markets, called the old and the new, both of which are held twice a week on Tuefdays and Saturdays: the latter is the principal one for provifions; the former being moftly frequented for tranfacting the manufacturing bufinefs of the town with the country traders. Moft of the ftreets are paved and lighted, and are guarded at night by about 200 watchmen. For the regulation of parochial affairs, Manchefter is divided into fourteen diftricts. It gives title of duke to the noble family of Montague, fome of whom have been diftinguifhed characters. In the paths of literary fame, however, it can claim little diftinction; but Byrom and Falkner may be properly ranked with what Fuller calls "the worthies of the place."

The environs of this town abound with old manfions, refpectable villas, and a number of modern feats. Ancoats-hall, the manorial manfion-houfe, is a venerable building, the parts of which are difpofed in a moft curious and grotefque manner. Hulme-hall, or Holme, is an edifice of a fimilar kind, exhibiting a remarkable fpecimen of ancient domeftic architecture. It ftands on the edge of a fhelving bank of the Irwell, and exteriorly offers to the view a moft romantic and picturefque object. Heaton-houfe, the feat of the earl of Wilton, lies about four miles to the north-eaft of the town. The houfe, a handfome modern ftructure of ftone, ftands on a commanding fituation, in the midft of a very noble park, finely decorated with venerable trees and numerous thriving plantations. The other principal feats are Trafford-houfe, Alkington, and Smedley-hall; near which laft is Broughton-hall, formerly the property of the Stanleys, earls of Derby. Every part of the furrounding country difplays the higheft ftate of agricultural improvement, and in times of profperity prefents one vaft fcene of enterprize and induftry. Beauties of England and Wales, vol. ix. Aikin's Hiftory of Manchefter, and its Environs, 4to. by J. Afton. The Manchefter Guide, 12mo. 1804. Whitaker's Hiftory of Manchefter, 2 vols. 4to. 1771.

Manufacture

MANUFACTURE is popularly used to signify the work itself; and by extension, the like work carried on independently in different parts of the country.

In this sense we say, the *cotton* manufacture, *woollen* manufacture, *silk* manufacture, *velvet* manufacture, *tapestry* manufacture, *muslin* manufacture, &c. manufacture of hats, stockings, &c.

By 23 Geo. II. c. 13. if any person exports any tools or utensils used in the silk, linen, cotton, or woollen manufactures, he forfeits the same, and 200*l.*; and the captain of the ship, having knowledge thereof, 100*l.* And if any captain of a king's ship, or officer of the customs, knowingly suffers such exportation, he forfeits 100*l.* and his employment, and is for ever made incapable of bearing any public office. And every person collecting such tools for exportation, shall on conviction forfeit them, and 200*l.* (See also 14 Geo. III. c. 71.) By 21 Geo. III. c. 37. the above penalties on the captain of the ship and officer of the customs are augmented to 200*l.*; and a person having in his custody, or procuring to be made any such tool, shall forfeit the same, and 200*l.*, and be imprisoned for twelve months. Prosecution on this clause to be within twelve months after the offence committed. By 22 Geo. III. c. 60. any person exporting any such tools, shall forfeit the same, and 500*l.*; and any officer of a ship, conniving at it, shall forfeit 500*l.*, and if it be a king's ship, forfeit also his office, and be incapacitated.

Much was done under the auspices of the magnanimous prince Edward III., for establishing our domestic manufactures, by prohibiting the exportation of English wool, and the importation or wear of foreign cloths or furs, and by encouraging cloth-workers from other countries to settle here.

MANUFACTURE, *Cotton*, one of the leading and most important branches of our national industry and commerce.

The history of its astonishing progress in the last century, the successive improvements in the machinery, which have been made by various inventors, and the extent of the trade, with other curious important facts, are detailed under the article COTTON: it is needless, therefore, to recapitulate these circumstances, and we shall proceed at once to describe this extensive manufacture, as conducted on the most improved system in some of our largest cotton-mills. Many of our readers may have viewed a cotton-mill with wonder, but not with intelligence, nor with leisure to trace the steps by which the wool from the bag ultimately assumes the form of a very fine thread. Bewildered by such a complication of machinery all in motion, very few, we imagine, are able to recollect, with distinctness and intelligence, the essential part of the processes by which the form of the cotton is so wonderfully changed. Such readers will not think a page or two misemployed, in giving a brief account of the different operations the cotton passes through, from the raw cotton or cotton wool, as imported, to the finished thread; and we shall afterwards enlarge upon each subject, and describe the machinery by which these operations are effected in the most expeditious and perfect manner. For the explanation of these, we have appropriated 13 of our plates, which are entitled *Cotton Manufacture*.

Cotton, it is well known, is the produce of a shrub in the warmer climates of the East and West Indies, and even in the more temperate countries which border on the Levant. It comes to us packed in bags, without any further

preparation than being pretty carefully picked out of the pod in which it grows; but ftill much dirt, hufk, and other impurities remain in it. The cotton wool is imported either in bags or in bales: the bags weigh from $1\frac{1}{2}$ cwt. to 5 cwt., and the bales ufually weigh $3\frac{1}{4}$ or $3\frac{1}{2}$ cwt. On arriving at the cotton-mill thefe are unpacked, and the contents examined at the fame time it is turned over and beaten with a ftick, and the grofs impurities picked out with the fingers. This is called *forting*, and the object of the beating is to foften and open the fibre of the cotton, fo as to expofe every part. The forting is performed immediately when the bags of cotton are opened, but it has ftill to undergo a fecond examination, called *picking;* the principal object of the firft examination, or forting, being intended to afcertain the quality of the cotton, and to find what kind of goods it is beft adapted for manufacturing, and in this examination the coarfeft impurities and yellow damaged parts are picked out.

After forting the cotton, it is carried to the *batting machine,* and the coarfer forts of cotton to the *opening machine,* which is known to the workmen by the name of *devil.* In the batting machine, the cotton is fpread upon a platform of ropes ftrained very tight, and a number of rods ftrike very fmartly upon it, by which they open the fibres and loofen the knots of cotton preparative to the fucceeding operations: at the fame time the violence of the batting loofens and fhakes out all dirt, duft, and cotton feeds, of which the cotton in its raw ftate contains a great number, and which would be very prejudicial to the operations of the more delicate machines. The cotton, when firft packed up in the bags, is compreffed very clofely, for the convenience of ftowage, and this condenfes it into a hard matted mafs; but the batting machine, ftriking it violently with fmall fticks, caufes the fibres, by their natural elafticity, and the motion occafioned among them, to gradually loofen and difengage themfelves, and the cotton, by repeated ftrokes, recovers all its original volume.

The *opening machine* has the fame objects, and produces the fame effects, though in a very different manner, as it confifts of a rapidly revolving cylinder, on which a great number of iron teeth, or fpikes are fixed, which tear and open the cotton againft other fimilar teeth, which are fixed in a ftationary half cylinder or hood, enclofing the other. The batting machine is ufed for the finer kind of cotton; and the opening machine, which acts in a more rapid though lefs effective manner, is employed upon the coarfer forts. After batting or opening, the cotton is again picked, to remove thofe finer particles of dirt which were before enveloped in the cotton, but are expofed by the operation of the machine. It is performed by women, who remove all extraneous matter, and every particle of yellow or damaged cotton. The perfection of the article to be produced, depends in a great degree on the care with which the picking is performed, and this is almoft the only procefs, in the cotton fpinning, which cannot be performed by machinery, becaufe it neceffarily requires a difcretionary power.

The cotton wool being picked clean, is next *mixed,* that is, the contents of different bags are mixed together with a view of obtaining a fimilarity in the quality of the cotton which is to be fpun. In this operation the greateft art of cotton-fpinning confifts, and it is that department in which experience alone guides the manufacturer. By a judicious mixture of different forts of cotton, fome fpinners will produce a very fine and capital yarn, from fuch cotton as would, if fpun alone, or improperly mixed, only produce coarfe and low priced goods. The mixture is effected by making a pile or heap, confifting of fucceffive layers, of the different kinds of cotton which are to be mixed; then by raking away a fmall quantity at a time from the edges of the heap, ftriking the rake from the top to the bottom, through all the different layers, the cotton will be very equally mixed. Sometimes the cotton wool is dyed, and different colours are mixed together. It is now fpread out, very evenly and regularly, upon a long cloth, which is rolled up and carried to the

Carding machine.—This confifts of a number of cylinders, covered with wire teeth or cards, and revolving with confiderable velocity in oppofite directions, nearly in contact with each other, and covered by a dome alfo lined with cards. The cotton, being introduced among thefe, is continually combed, or carded, by the teeth, until almoft every individual fibre is feparated and drawn ftraight, and every little knotty and entangled part difengaged. By paffing gradually through the machine from one cylinder to another, the cotton is difperfed lightly and evenly among the teeth over the whole furface of the laft, or finifhing cylinder, from which it is detached by the mechanifm in a continued fleece. This is drawn off, and lapped upon a cylinder turned flowly round by the machine, until the fleece has made a great number of turns upon the cylinder: it is then broken off, by dividing it at one part, fo that it forms a fleece called a lap, which is the length of the circumference of the cylinder, and confifting of fifteen or twenty thickneffes, by which admirable contrivance very great regularity is obtained in the thicknefs of the lap, becaufe if any one part of the fleece produced by the machine is thinner or thicker than it ought to be, in confequence of any irregularity in the fpreading of the cotton-wool upon the cloth, previous to carding, fuch irregularity will have no fenfible effect upon the ultimate thicknefs of the lap, becaufe it is compofed of thirty or forty ftrata, and there is no probability that the inequalities of thefe feveral ftrata will fall beneath each other, but every chance that they will be equally difperfed through the whole, and thus correct each other. The lap, when taken off, is laid flat on a cloth, which, with it, is rolled up and conveyed to a fecond carding-machine, called the *finifhing card,* while the firft is called the *breaker.* In this fecond card it undergoes a fimilar procefs to the firft, but inftead of the fleece being received on a cylinder, it is contracted by paffing through a funnel, in which the fleece, being hemmed in on both fides, is gradually contracted to a thick roll, which may be continued to any length as long as the machine is fupplied with cotton. This roll or band of cotton is drawn off between two rollers, which comprefs it into a pretty firm, flat ribband, about two inches broad. The rollers deliver it into a tin can, placed to receive it, and in this it is removed to the

Drawing Frame.—This machine confifts of feveral pairs of rollers, between which the cotton is paffed, and every fucceffive pair it is drawn through moves, by means of the wheel-work, with a greater velocity than thofe preceding it, fo as to ftretch out the band or fliver of cotton, in the fame manner as it would be drawn out, if one part of the fliver were held between the finger and thumb of one hand, and another part, at an inch or two diftant, being held in the other hand. Then by drawing the two hands afunder to the extent of four inches, it is evident two inches in length of the cotton fliver would be extended or drawn out to four inches. In like manner, the firft pair of rollers through which the fliver paffes, are preffed together with a fufficient weight to hold the cotton firmly between them. The fecond pair of rollers are fituated at one or two inches diftant, and are made by the wheel-work to revolve more fwiftly than the firft. The difference of velocity, however, is but fmall, though the confequence is, that the fliver will be lengthened in the fame

proportion; for the fecond rollers take up the cotton much fafter than the firft pair will deliver it out: it muft, therefore, be either forcibly pulled through between the firft rollers, or it muft be ftretched a little, by the fibres flipping among each other, or it muft break. When the extenfion is fmall, the only effect of it is merely to begin to draw the fibres (which are at prefent lying in every poffible direction) into a ftraight and parallel pofition, which is moft favourable for the fubfequent extenfions. The drawing frame contains a third, and fome of them a fourth pair of rollers, by which the fliver undergoes a fecond or third draught; but the combined effect of all thefe drawings is generally to extend the fliver to four times the length it was when firft put to the machine. But as this would reduce the fliver to one-fourth of the fize, which is not intended in this ftage of the procefs, four ends or flivers are introduced between the rollers together, and being drawn into one, which is four times the length, it will of courfe be of the fame fize as any one of the four which is put in. This drawing procefs is repeated three or four times, and the alteration it makes in the cotton is to equalize the fize of the fliver, on the fame principle as before defcribed of the breaking card, *viz.* by repeatedly combining four together, and drawing them into one: it alfo difpofes the fibres longitudinally and in the moft perfect ftate of parallelifm. The operation of carding effects this in a certain degree; yet the fibres, though parallel, are not ftraight, but many of them doubled, as may eafily be fuppofed, from the teeth of the cards catching the fibres fometimes in the middle, which become hooked or faftened upon them.

Though the general arrangement of the fibres of a fliver from the finifhing card is longitudinal, yet they are doubled, bent, and interlaced in fuch a way, as to render the operation we are now fpeaking of abfolutely neceffary.

When the cardings have been paffed four or five times through the drawing frame, every fibre is ftretched out at full length, and difpofed in the moft even and regular direction, fo that each fibre will, when twifted into a thread, take its proper bearing, in confequence of every one being ftraightened and having the fame tenfion.

The fliver in this ftate prefents a moft beautiful appearance, being fo extremely regular in its fize, and all the fibres drawn fo ftraight, that it bears a fine gloffy or filky appearance. It is upon this fliver or ribband of cotton wool that the operation of fpinning begins. The general effect of the fpinning procefs is, to draw out this maffive fliver, and to twift it as it is drawn out: but this is not to be done by the fingers, pulling out as many fibres of the cotton at once as are neceffary for compofing a thread of the intended finenefs, and continuing this manipulation regularly acrofs the whole end of the ribband, and thus, as it were, nibbling the whole of it away. The fingers muft be directed for this purpofe by an attentive eye; but in performing this by machinery, the whole ribband muft be drawn out together and twifted as it is drawn. This requires great art and very delicate management: it cannot be done at once, that is, the cotton roll cannot be firft ftretched, or drawn out to the length that is ultimately produced, from the tenth of an inch of the fliver, and then twifted. There is not cohefion enough for this purpofe, it would only break off a bit of the fliver, and could make no further ufe of it; for the fibres of cotton are very little implicated among each other in the fliver, becaufe the operation of carding and drawing has laid them all parallel in the fliver; and though compreffed a little, by its contraction in the card from a fleece of twenty inches to a ribband of two, and afterwards compreffed between the rollers of the drawing frame, yet they cohere fo flightly, that a few fibres may be drawn out, without bringing many others along with them. For thefe reafons, the whole thicknefs and breadth of two or three inches are ftretched to a very minute quantity, and then a very flight degree of twift is given it, *viz.* about two or three turns in the inch, fo that it fhall now compofe an extremely foft and fpungy cylinder, which cannot be called a thread or cord, becaufe it has fcarcely any firmnefs, and is merely rounder or flenderer than before, being ftretched to about four times the former length. This is called *roving*, and the operation is performed in the

Roving Frame.—This machine is conftructed in a great variety of forms, but all of them have the fame object in view, *viz.* to draw out the fliver, fo as to reduce it from a large band to a coarfe and loofe thread: but as this extenfion would render it fo extremely tender, that it would fcarcely hang together in paffing through the fucceeding machines, the roving frame, immediately after having drawn and extended it to the intended fize by rollers, operating in the fame manner as the rollers of the drawing frame, gives it a very flight twift, as before mentioned, and this loofe thread, which is called the roving, is the firft rudiment of a thread. Although it is extremely tender, and will not carry a weight of two ounces, it is much more cohefive than before, becaufe the twift given to it makes all the longitudinal fibres bind each other together, and comprefs thofe which lie athwart; therefore it will require twice the force to pull out a fibre from among the reft, but ftill not near enough to break it. In drawing a fingle fibre others are drawn out along with it, and if we take hold of the whole affemblage in two places, about an inch or two afunder, we fhall find that we may draw it to near twice its length, without any rifk of its feparating in any intermediate part, or becoming much fmaller in one part than another. It feems to yield equally over all parts.

Our readers will now perceive, that thefe proceffes will enfure all that is wanted, and prepare a roving that is uniform, foft, and ftill very extenfible: in fhort, fit for undergoing the laft treatment of fpinning, by which it is made a fine and firm yarn.

It is evident that the roving produced by thefe operations muft be exceedingly uniform. The uniformity really produced exceeds all expectation; for even although there be fome fmall inequalities in the carded fleece, yet if thefe are not matted clots which the card could not equalize, but only confift of a little more thicknefs of cotton in fome places than in others, this inequality will firft be diminifhed by the lapping of the fleece in the breaking card; and when fuch a part of the fliver comes to the firft roller of the drawing frame, it will be rather more ftretched by the fecond than a thin part would be. That this may be done with greater certainty, the weights of the firft rollers are made very fmall, fo that the middle part of the fliver can be drawn through, while the outer parts remain faft held.

Such is the ftate of the roving as prepared by the roving frame. All the preceding proceffes are to be confidered as the preparations: and the operation of fpinning is not yet begun. Thefe preparations are the moft tedious, and require more attendance and hand-labour than any fubfequent part of the procefs. For the flivers from which the rovings are made are fo light and bulky, that a few yards only can be piled up in the cans fet to receive them from the carding and drawing: a perfon muft therefore attend and watch each roller of the drawing and roving frames, to join frefh flivers as they are expended. It is alfo the moft important depart-

ment in the manufacture; for as every inch will meet with precisely the same drawing and same twisting in the subsequent parts of the process, therefore every inequality and fault of the sliver, indeed of the fleece as it quits the finishing card, will continue through the whole manufacture, in a greater or lesser degree, being only diminished, not corrected, by the drawing, doubling, &c. The spinning of cotton-yarn now divides itself into two branches. The first performed by what were called jennies, when worked by the hand, but since they are moved by the power of a mill, they are called mules: the manner of action resembles the ancient spinning with distaff and spindle. The second method, called spinning of *twist*, or *water-spinning*, because it was the first spinning performed by a water-wheel, is in imitation of the spinning with the fly-wheel, or jack and flyer. The two methods differ in the same manner, as the old wool or cotton-wheel differs from the spinning with the flax-wheel. Mr. Arkwright's chief invention, the substitution of the machinery for the immediate work of the human finger, was at first only applied to the manufacture of twist, or water-spinning. We shall, therefore, first direct our attention to this.

The water-spinning process is little more than a repetition of that gone through in making the first slivers or rovings, which are formed on bobbins, either by the roving frame, or are afterwards bound on bobbins by the hand. These bobbins are set on the back part of the

Spinning-frame, in which the roving is drawn, and extended to any required degree of fineness; and the proper twist being given to it, forms it to the required thread. The spinning-frame is provided with systems of rollers, in the manner of the drawing-frame, through which the roving passes, and is drawn out according to the size of the thread which is required to be spun, which varies from four to seventeen times; and it is then twisted more or less, as the thread is required to be hard or soft: therefore, the spinning process scarcely differs from the roving, except in the twist that is given it, after the last stretching, in its length. This is much greater than the roving, being intended to give the yarn hardness and firmness, so that it will afterwards break rather than stretch any more. The perfection of the ultimate thread or yarn depends, in a great measure, on the extreme softness of the roving; for it is this only which makes it susceptible of an equable stretching, all the fibres yielding and separating alike: and this property will be greatly influenced by the quantity of twist given by the roving-frame. For these points no very distinct rule can be given: it varies in different mills, and with different species of cotton wool, as may be easily imagined. The immediate mechanism, or manipulation, must be skilfully accommodated to the nature of that friction which the fibres of cotton exert on each other, enabling one of them to pull others along with it. This is greatly aided by the contorted curled form of a cotton fibre, and a considerable degree of elasticity which it possesses. In this respect it greatly resembles woollen fibres, and differs exceedingly from those of flax; and it is for this reason that it is so extremely difficult to spin flax in this way: its fibres become lank, and take any shape by the slightest compression, especially when damp in the slightest degree. But beside this, the surface of a cotton fibre has a harshness or roughness, which greatly augments their mutual friction. This probably is the reason why it is so unfit for tents, and other dressings for wounds, and is refused by the surgeons even in the meanest hospitals. But its harshness and elasticity fit it admirably for the manufacture of yarn. Even the shortness of the fibre is favourable; and the manufacture would be very difficult, if the fibre were thrice as long as it generally is. If it be just so long that, in the finished thread, a fibre will rather break than come out from among the rest, it is plain that no additional length can make the yarn any stronger, with the same degree of compression by twining. A long fibre will indeed give the same firmness of adherence, with a smaller compression by twining. This would be an advantage in any other yarn; but in cotton, the compression is already as slight as can be allowed: were it less, it would become woolly and rough by the smallest usage; and it is already too much disposed to teazle out. Now, suppose the fibres much longer, some of them may chance to be stretched along the sliver through their whole length. If the sliver is pulled in opposite directions, by pinching it at each end of such long fibre, it is plain that it will not stretch till this fibre be broken up, or drawn out; and that while it is in its extended state, it is acting on the other fibres in a very unequable manner, according to their positions, and renders the whole apt to separate and draw more irregularly. This is one great obstacle to the spinning of flax by similar machinery.

Mule-spinning.—A great proportion of the cotton is spun in the mule instead of the water-frame. The preparation it undergoes for either method is the same; at least the processes are similar, except that the quantities of draft, and some other particulars, may be varied in the preparation of the cotton which is to be thus spun in this machine, which is called a mule, either because it is a kind of machine which might easily be turned by a mule, or more probably because it is a sort of mongrel, partaking of the nature of both drawing and spinning, or uniting the action of both the roller and spindle. It consists of three sets of fluted brass rollers, the flutes of which turn into each other. The first set goes faster than the second, and the second faster than the third; between which, when the sliver of carded cotton enters, it is a little lengthened out between the first and second, and farther still between the second and third; after passing which, it is slightly twisted by the rapid circular motion of the spindle. This has the same effect as the spinning-frame; but the quantity of draft between the rollers, or extension of the sliver, is not, like the water-frame, to the full extent which the thread is intended to be. The remainder of the stretching is performed in this manner: the spindles of the mule, which give the twist to the thread, are fitted in a frame, so that they can be moved backward and forward, in a straight line, to and from the rollers; a certain length of the roving being therefore given out by the rollers, the spindles are removed backward to take it up as fast as it comes, and in this motion they twist it slightly: at the same time, but after a certain quantity of the roving, a yard for instance, has been given out by the rollers, their motion ceases; but the spindle continues to recede from them, another half yard for instance, continuing to twist the thread all the while. By these means, it is evident that the thread will be stretched from a yard to a yard and half in length: by this contrivance, the cotton will bear a greater degree of extension than any other, because it is constantly twisted at the same time that it is extended in length.

The invention of mules forms quite an epoch in the history of the cotton trade. A vast improvement was made, about 35 years ago, by the introduction of the spinning jennies, by which from twenty to forty spindles were turned at a time. The spindles were the same as the mule, and had the same motion; but this machine was not provided with rollers to draw out the cotton, previous to twisting, merely depending upon the stretching, to give it the proper extension requisite to form the roving into a thread. But the combination of the jenny with sir Richard Arkwright's invention of drawing, by rollers, forms a method superior to both, at

least for fine goods. The method of stretching gives the means, as we have before mentioned, of very great extension; but if this be carried so far as to draw out the coarse loose roving to a fine thread, there will be great danger of its drawing irregularly, that is, more in one place than another. In the original method by the jenny, the rovings were prepared by the hand-wheel: they were loose, coarse, untwisted threads, partaking somewhat of the nature of cardings, though approaching in some degree to spun twist. They were obliged to be prepared by the hand-wheel, because the cardings, which were prepared by hand-cards, were in detached pieces of a certain length, and regularly tapering towards each end: the joining of these together, in such a manner as to produce an equal and regular roving, required a care and attention which could not be effected by machinery.

The combination of sir R. Arkwright's system of preparation with the jenny produced the mule, which, without the defects of its original, spins in the most expeditious and perfect manner. The advantage of this mode of preparing the threads over that of the jenny is, that the fibres of the cotton are all laid longitudinally, and nearly in as small number as is wanted, before they are begun to be much twisted; by which means, threads of any required fineness are made much stronger than they were from rovings, made upon the spindle of the hand-wheel spun in the jenny, which twisted them too much in the first instance; and in the subsequent extension or stretching, by the removal of the spindle, for rendering them finer, many of the fibres were necessarily broken. On one of these mules 240 threads are often spun at once; and two of them may be managed by one woman, with a child to tie the threads which may occasionally break.

It is needless, as the jenny has become an obsolete machine in the cotton manufacture, to enter into any further details, particularly as the mechanism so nearly resembles the jenny still used in the WOOLLEN *manufacture*. See that article.

The reader moderately acquainted with mechanics, cannot but perceive that by each of the operations now described, the cotton-wool is prepared, and drawn into a fine strong thread, by repeatedly drawing the sliver till its fibres become straight, then reducing it in the roving frame to a coarse thread, and by a slight twist giving it sufficient strength to bear such an extension as will reduce it to the size intended, and then it is immediately twisted into a hard thread. All these processes are only a substitute for a single pull of the finger and thumb of the spinner, which she accommodates precisely to the peculiar condition of the lock of wool which she touches at the moment: she can follow this through all its irregularities, and, perhaps, no two succeeding plucks are alike. But when we cannot give this momentary attention to every minute portion, we must be careful to introduce the roving in a state of perfect uniformity, and then every inch being treated in the same manner, the final result will be equable, and the yarn will be uniform.

The thread being now finished, either by the water-frame or mule, it is carried to the

Reel, by which it is taken off the bobbins of the spinning frame, or the cops of the mule, and formed into hanks. The hank is a measure in cotton trade, composed of seven *leys*, each of 120 yards in length. The reel or frame round which the thread is wound is one yard and a half in circumference, and at every 80 turns (or *bouts*) which it makes, the 80 turns of the thread are tied together to keep them separate, and this measures out 120 yards, which is called a ley: but the thread is not cut at the ley, it is continued to be wound on the reel, till seven such leys, or 840 yards, are reeled: it is then cut and called a hank, which is tied up.

The different sizes of cotton yarn, or thread, are denominated according to the number of these hanks which will weigh a pound. The hank of 840 yards in length is the measure used in all English cotton-mills, and thus affords a very accurate and convenient standard for the size of the cotton. The number is ascertained by weighing each individual hank in a little *weighing instrument*, which shews by an index what number of such hanks will weigh a pound. Each hank being twisted up is suspended on the hook of this instrument, and the number being ascertained, the hank is put on a proper shelf till they are all sorted. Then by a table on purpose it is seen how many hanks of any number will weigh 10lbs. and this number being counted out from any one shelf, is packed up in the *bundling press*, and tied in papers, marked, and sent away for market. Sometimes, the cotton intended for weaving is warped in the warping-mill before it is sent away from the mill: this saves the weaver an immense deal of trouble.

Some of the twist is wound on quills for the shuttle; and others, again, are formed into hanks, some of which are tightly bound round at certain intervals previous to their being dyed, in order to prevent the parts so tied from taking the colour. This is done that the threads may be disposed to warp in the weaving loom, so as to produce the clouds which are seen in various species of the cotton goods, especially ginghams.

Some of the cotton thread is dyed in the hank, and other cotton which is intended for sewing, knitting, &c. or to weave fine goods, is bleached; and because in this process, or in dyeing, some shrinking takes place, it is wound from the hanks upon bobbins again by the *winding machine*, and from these bobbins it is again reeled into hanks, in which it is packed up and sent to market: other cotton thread for sewing, mending, and domestic use, is wound into balls of a figure resembling a cask, and the many intersections of the thread are so managed as to produce a very beautiful appearance.

The denominations of the quality of the different kinds of cotton threads are chiefly divided into *yarn* and *twist*, and this is called *mule* twist, or *water* twist, as it is spun either in the mule or water-frame. That thread which is denominated *water-twist*, is used for weaving calicoes, &c. It is spun hard, that is, with a great deal of twist, so that it forms a strong hard thread. It is manufactured of all numbers, from 10 to 60 hanks *per* pound.

The *mule-twist* is used for weaving muslins and the finest cotton goods. The essential differences between this and the water-twist are, that the mule produces much finer articles than are attempted on the water-frame, at the same time it makes a softer thread. As it requires much less power to work it than the water-frame, the manufacturer spins every thing in the mule which will admit of it; but it will only produce the soft kinds of thread. The mule will spin all numbers, from the lowest to 150 or 170 hanks *per lb.* The trade of Manchester is chiefly mule spinning, whilst the water-twist is mostly spun in the country by water-mills, because the great power it requires is too expensive for steam-engines, at least the water-mills have the advantage, being usually in situations where they have their power at a less expence than those turned by steam-engines.

Stocking yarn is spun softer than twist, and two threads are afterwards doubled together in the doubling machine, and then slightly twisted round each other in the twisting ma-

chine. Sometimes one of the threads is dyed black, or blue, before the twiſting, and then it produces a ſpeckled thread, which is called one-thread white. This yarn is chiefly uſed in the ſtocking-frame; it is ſpun in all numbers, from 10 hanks in the pound up to 60. The threads of ſtocking yarn are but ſlightly twiſted, ſo that its compoſition of two threads is always diſtinctly viſible.

Sewing cotton is made either from twiſt or cotton yarn doubled, and twiſted very hard together by paſſing it a ſecond time through the ſpinning frame, ſo as to form a ſtrong thread, which may be compared to a ſmall rope, as the two threads make one very compact and defined thread.

Mending cotton is the ſame as ſewing, but of leſs twiſt: indeed the diſtinction is trifling.

Knitting cotton is twiſted with two or three threads, but not ſo hard twiſted as ſewing cotton, though it is harder than mending. This cotton is frequently bleached after it is twiſted.

Candlewick cotton is a very looſe coarſe thread, made from the cheapeſt and moſt inferior kind of cotton: being only intended for the wick of candles, no great care is uſed in the manufacturing. A great deal of candlewick is made from tow which is bleached, and makes an article ſomething like the cotton in appearance, but by no means equal to it in quality. This is known by the cant term of *bump*, and many large mills are employed in ſpinning it. The cotton candlewick is known by the name of *Turkey*, which is made from Smyrna or other cheap inferior kinds of cotton. It is ſpun generally about $10\frac{1}{2}$ to 11 hanks *per lb.*, and ſent off to market wound up in large balls. Oxford candlewick is made from inferior cotton, about ſeven hanks to the pound. Wiltſhire candlewick is made from waſte cotton, about No. 7. Theſe articles are ſpun without the care requiſite for yarn or twiſt: they are uſually ſpun by mules, and in ſome mills for coarſe goods they do not take the trouble to form them into rovings at all, but ſpin the candlewick at once from the ſlivers, as prepared by the drawing-frame.

To purſue the progreſs of the cotton after being ſpun into twiſt, we muſt remove from the cotton-mill to the cottage of the weaver. Here, the warp being fixed in the loom, or, in the language of the weaver, warped, it is divided to give paſſage to the weft in the ſhuttle, either by two, three, or more treadles: or if the pattern or courſe of changes in the order of raiſing and depreſſing the threads of the warp be various, ſo that the weaver could not manage the requiſite number of treadles, it is done by a great number of ſtrings which paſs over pullies above the loom, and are drawn one after another by a little boy, above whoſe head they are diſpoſed in two rows by the ſides and between two looms. Theſe looms are, therefore, called draw-boys. Theſe boys will ſhortly be ſet aſide for machinery, which is rapidly introducing a ſubſtitute. For the formation of ſprigs, &c. of various colours, there are often as many ſhuttles as colours, or a number of little ſwivel looms, ſuch as they uſe for the weaving of tapes, introduced occaſionally, as many as there are ſprigs in the breadth of a piece. Quiltings appear to be two diſtinct cloths, tied as it were together by ſtitches, which go through both cloths, and in ſome caſes, as in bed-quilts, there is a ſhuttle which throws in a quantity of coarſely ſpun cotton, to ſerve as a kind of wadding. The counterpanes are woven with two ſhuttles, one containing a much coarſer weft than the other; the coarſer of the threads is picked up at intervals with an iron pin, rather hooked at the point, ſo as to form knobs diſpoſed in a ſort of pattern.

When the goods are come from the loom, moſt ſorts of them, previouſly to being bleached, are fired or dreſſed, by being drawn, and that not very quickly, over red-hot cylinders of iron, by which the ſuperfluous nap is burnt off. To ſee ſuch an operation performed upon ſo combuſtible a ſubſtance, naturally fills a ſtranger with the utmoſt concern and aſtoniſhment. They are then waſhed in a wheel with ſoap and water, and having been well ſcoured with an alkaline lixivium, are dipped in the oxygenated muriatic acid, diluted to its proper ſtrength. Theſe preparations are repeated alternately, till the goods have attained the requiſite whiteneſs; and between each dipping they are laid out upon the ground, and expoſed to the action of the ſun and air. When completely bleached, they are either ſmoothed upon long tables with ſmoothing irons, or calendered; that is, ſtretched and preſſed between a courſe of rollers, by which they acquire a fine gloſs. Calicoes are printed exactly in the ſame way as the kerſeymeres in Yorkſhire, but the works are uſually upon a much larger ſcale. See Printing.

Thickſets, corduroys, velveteens, &c. are cut upon long tables, with a knife of a conſtruction ſomewhat like the ſting of a waſp, terminating in a very ſharp point, defended on each ſide by a ſort of ſheath. This point is introduced under the upper courſe of threads which are intended to be cut, and with great eaſe carried forward the whole length of the table.

The rapid increaſe of the cotton trade appears to have been owing, in a great meaſure, to the more liberal introduction of machinery into every part of it, than into any other of our ſtaple manufactures. The utility and policy of employing machines to ſhorten labour, have been a ſubject which has exerciſed the pens of many ingenious writers, while their introduction into almoſt every branch of manufacture has been attended in the outſet with much riot and diſorder. They are undoubtedly wonderful productions of human genius, the progreſſive exertions of which neither can nor ought to be ſtopped; they enable a manufacturer to produce a better article than can be made by the hand, in conſequence of the uniformity and certainty of their operations, and at a much lower price, in conſequence of the vaſt quantities of goods they are capable of performing. They thus ſupport the credit of our manufactures abroad, and enable us under the vaſt load of taxes, and conſequent increaſe in the price of every neceſſary of life, to meet our foreign competitors with advantage at market. They can even allow the goods to furniſh in their paſſage a conſiderable revenue to government. And although they do, undoubtedly, on their firſt introduction, throw ſome perſons out of employ, by changing the nature and courſe of buſineſs, they almoſt immediately make up for the inconvenience by aſtoniſhingly multiplying the abſolute quantity of employment. If they have taken away work from carders and ſpinners, they have returned it them back tenfold, as winders, warpers, weavers, dreſſers, dyers, bleachers, printers, &c.

It is this machinery which we have now to explain. An extenſive cotton mill contains moſt intereſting ſpecimens of human ingenuity and reſource, and ſhews in a ſtriking manner what may be done, when the talents of a great number of individuals are directed to one common object, and where the moſt [illegible] is of ſuch importance (from the frequent repetition of it which is neceſſary) as to become worthy the conſideration of the manufacturer to deviſe machinery for accompliſhing it in a better or cheaper manner. There is, in the cotton trade, ſuch a ſpirit of improvement, that they have, as a body, leſs prejudice in favour of old eſtabliſhed cuſtoms than perhaps any other claſs of

this is doubtleſs a reaſon of the great perfection of their art,

as they have made trials of new ideas, without thofe years of reflection which men in other trades require before they will venture to embark in any new improvement, though ever fo promifing and favourable in appearance.

Our readers, who are unacquainted with the fubject, will now by this fketch have obtained fuch a general idea of the cotton manufacture, as will enable them to comprehend the technical terms which are neceffary to be ufed in the fubfequent explanation of the machinery, and thofe references which muft fometimes be made from one procefs to another. A large cotton mill is generally a building of five or fix ftories high: the two loweft are ufually for the fpinning frames, if they are for water twift, becaufe of the great weight and vibration caufed by thefe machines. The third and fourth floors contain the carding, drawing, and roving machines. The fifth ftory is appropriated to the reeling, doubling, twifting, and other operations performed on the finifhed thread. The fixth, which is ufually in the roof, is for the batting machine, or opening machine, and for the cotton pickers, who for a large mill are very numerous. This laft is not always fo occupied, many manufacturers thinking it better to have out-buildings for thefe parts of the procefs, and only to have fuch parts in the mill as require the aid of the large water-wheel, or fteam-engine, which turns the whole mill. If the mule is ufed for fpinning inftead of the water frame, then the cards are ufually put below, becaufe they are then the heavieft and moft powerful machinery.

The firft machine we fhall defcribe is the *Batting machine*. *Plate* II. *Cotton Manufacture*, *fig.* 1, is an elevation fideways, and *fig.* 2. an elevation endways, the frame being in both defcribed by dotted lines, that it may not obfcure the mechanifm: *figs.* 3, 4, and 5, are detached parts of the machine. The moving power is communicated by the mill to an horizontal axis, on which the fly-wheel, C, is fixed, to regulate the motion. On this axis four cranks are formed, as fhewn at *i*, *i*, *i*, *i*, making equal or right angles with each other; and connecting rods, *i*, *h*, being extended from thefe cranks to the lower ends of the levers *g*, *g*, which are moveable on the centres *f*, caufe them to vibrate alternately when the cranks are turned. There are four of thefe levers fituated on each fide of the machine, all the four on each fide having one common centre at *f*. Each crank on the main fpindle has two connecting rods upon it, to actuate two different levers; but which being fituated on oppofite fides of the machine, of courfe receive their motion alternately: at the upper ends, *e*, *e*, of the levers, which, as the figure fhews, are much longer than the lower ends, that is, the centre of motion, *f*, is placed confiderably beneath the middle of the levers. At the upper ends, *e*, *e*, of the levers joints are formed, by which they are connected with rods, *x*: thefe perform the batting, by ftriking in the manner we fhall defcribe upon the platform A, where the cotton is fpread. This platform is formed of a long cord, which is repeatedly paffed over two rollers, one of which is fhewn at *m*, and the other is at the oppofite end of the machine: the cord paffing round from one of thefe to the other twenty or thirty times, and having all the turns made parallel to each other, at about an inch afunder, it forms an horizontal platform for the fupport of the cotton; but to fill up the interftices between thefe ropes another ftationary fet is placed. Thefe are ftrained between two fixed beams of the frame, as fhewn in *fig.* 4, which is a plan (and a fection is fituated immediately beneath it.) The roller *m*, *fig.* 1, is kept in continual rotation by a train of toothed wheels, marked *k k k k l*, which communicate the motion by a pinion on the main axis from one to another, and laftly to the roller by means of a contrate wheel *l*, in which a pinion acts. By thefe means the endlefs rope, which extends from one roller to the other, and forms one-half of the platform for the cotton, is in conftant motion, and the cotton which is laid upon it at one end traverfes flowly to the other, receiving in its paffage the blows of the rods *x*, which ftrike upon it alternately. Their action is produced in this manner; the levers, *g*, *g*, are forked at the upper ends, as fhewn in *fig.* 5, fo as to afford a fufficient length of bearing for a fhort axis 3, 4, on which the rod *x* moves. The fmall dotted circle 3, in this figure, reprefents the place where the rod unites with the axis, or rather where a fmall iron tube proceeds from the axis; and in the end of this the wooden rod, *x*, is inferted, and held faft by means of a fcrew clamp, or hoop, furrounding the end of the tube, and compreffing it upon the rod, one fide of the tube being fplit down to admit of this compreffion. Upon the fame axis as the rod *x* are fixed two fmall pullies 1, 2, to each of which a ftrap is attached, and, after making a turn round their refpective pullies, thefe are conducted away to a fixed part of the framing, in the manner fhewn in *fig.* 1. Thefe ftraps are of fuch a length, as to hang loofe during a greater part of the time; but when, by the motion of the top of the levers *g*, *g*, *fig.* 1, they come to their tenfion, they operate upon the pullies 1 or 2, *fig.* 5, and turn them half round with their axis, at the fame time turning over the rods *x*, *x*. This motion is more clearly explained by *fig.* 3, which will, at the firft view, be feen to be only a detached fection of the parts already defcribed in *fig.* 1. A reprefents one of the vertical levers (*g*, *fig.* 1.), and F its centre of motion, upon which it traverfes from the pofition A, to that reprefented by the dotted lines B, by the action of the crank rod joined to the lower end of it, as before defcribed; therefore the two pofitions, A, B, are to be confidered as the extremes of its movement. E reprefents the pullies which are fixed on the axis of the batting rod *h*, the two appearing as one in this view. One of the ftraps of thefe pullies is faftened by one end at *n* to a fixed part of the frame, and the other end is made faft to the pulley at *o*. The other ftrap has one of its ends faftened to the pulley at *k*, while the oppofite end is attached at *i* to a lever *i m*, whofe centre, G, is ftationary. The lower end, *m*, of the lever has a ftrap attached to it, which proceeds to the lever A, and is made faft thereto at *l*. The operation of this conftruction may be thus explained: in the pofition B, the ftrap, *i f*, (anfwering to *i k* in the other pofition) hangs flack, as in the figure, while the other ftrap, *r n*, has come to its tenfion, and has turned over the batting rod to the pofition *g*. Now, fuppofe by the action of the crank rod the lever is moved towards the pofition A, it proceeds for fome diftance with the rod *g*, remaining horizontal, and merely drawing along endways; but when it is advanced rather more than half way, the ftraps, *l m* and *i k*, come to their tenfion: the former pulls the lower end, *m*, of the lever, *m i*, after it, and, of courfe, the upper end, *i*, at the fame time moving in an oppofite direction, draws the ftrap, *i k*, with it, turning the pulley E, and the batting rod attached to it, over into the pofition *b*, and ftriking on the cotton fpread on the platform. This motion is performed almoft inftantaneoufly, becaufe, the ftrap *i k* being drawn in one direction, whilft the centre of the pulley it is faftened to moves in an oppofite direction, thefe motions caufe the pulley E, and the batting rod which is attached to it, to turn over with a double velocity, to what it would have had if fimply actuated by the motion of the lever A; fo that this rapid motion caufes the batting rod to ftrike with an exceedingly fmart ftroke upon the cotton laid upon the platform. In

returning back again to the position B, which the crank causes it to do very shortly after having made the stroke, it proceeds, as before mentioned, to beyond the half way, with the straps hanging slack and having no action; but when it has passed rather more than half way, the strap, *n f*, becomes tight, and turns the pulley over, bringing the batting rod to the position *g*, ready to make another stroke; but in turning it over to this position, the rod does not move with such velocity as to strike a blow upon the cushion *d*, *fig*. 1, which is placed to receive it, because the strap, *f n*, is fixed to a stationary point *n*, instead of having a motion in the opposite direction to the lever, as the other strap *l k*, which caused the stroke upon the cotton. In *fig*. 1. the frame is marked B, and *o*, *o*, represent the levers *i*, C, *m*, *fig*. 3. The lever *g*, *fig*. 1, which is nearly in a vertical position, appears to have two of the rods *x* proceeding from it in opposite directions. This appearance is occasioned by there being two levers in that position exactly behind each other, though they are moving in opposite directions, therefore one of the rods, *x*, remains upon the cotton at A: the other, which belongs to the lever concealed behind, is represented as just rising from the cushion *d*. *Fig*. 2. is an edge view of the machine, where A represents the strap which communicates motion to the machine by means of two pullies, called the live and dead pulley, from the circumstance of one pulley being fitted loose, so as to slip round freely upon the axis, whilst the other pulley is fixed fast upon the axis: therefore, when the endless strap is shifted upon the loose or dead pulley, it slips round without communicating any motion to the machine; but when it is shifted on the other pulley, the machine immediately commences its motion. E represents the fly-wheel on the opposite end of the axis, and B, B, B, B, are the four cranks which actuate the levers C, C, C, C: *f* is one of the rollers on which the endless cord or platform, D, is wound, and it extends from this to a similar roller on which a wheel, *g*, is fixed; then returning again to the roller, *f*, and after having made in this manner more than twenty turns round the two rollers, the ends are strained tight and spliced together, so that it appears like *fig*. 4, forming a platform on which the cotton lies, and is regularly carried from *f* to *g* by the motion given to the roller *f* through the cog-wheel *e*, and the other train of wheel-work which communicates with the main axis, as before described. At the sides of the platform two boards are fixed which form a trough, and prevent the cotton getting off sideways. The batting rods strike down through openings or notches *d*, *d*, *d*, *d*, cut in these boards. The dotted lines represent other notches to admit the batting rods on the opposite side of the machine, which, as this figure shews, are not precisely opposite, but the rods on one side strike in the interval between those of the others. The cotton, after passing along with the moving cords through the machine, is thrown off, and falls upon a table *i*, *fig*. 2, which is covered with an endless canvas cloth, and is strained over two rollers *b*, *k*, which are kept in constant motion by an endless band passing round the wheels *b* and *g*. By this motion of the cloth the cotton is conveyed away as fast as the batting machine finishes it, and is taken off this table by women, who discharge it into baskets, in which it is conveyed to the picking room.

The opening Machine, or *Devil*.—This machine comes next to be described, being used for similar purposes as the batting-machine, though it is not to be considered as one of the same series, being used for the coarser sort of cotton in the same stage as the batting engine is used for the finer sorts. *Plate* III. contains drawings of one of these machines, in which *fig*. 1. is a plan, and *fig*. 2. a section. In either of these A A represents a cylinder, put in rapid motion by an endless band passing round the pulley R. This cylinder has a great number of teeth fixed into its periphery, and the hood or arch, E E E E, contains a set of similar teeth or spikes fixed withinside it. This casing consists of a number of parallel bars or lags, one of which is shewn in perspective in *fig*. 5: these are supported by an iron semicircle B B, *fig*. 3, also erected on each side P P, projecting from it, and every lag has a notch, or cleft, cut at each end, by which they are hung on these pins, forming a very simple manner of fixing the lags; but they can be easily removed when required, to clear the machine from the flue and impurities which it gets out of the cotton. In front of the cylinder a pair of feeding rollers, *d*, *d*, are fixed, through which the cotton passes to the machine: these rollers are fluted and placed immediately above each other, as shewn in *fig*. 2; then a heavy weight L, being suspended from the pivots of the upper roller, causes them to press together with a sufficient force to draw cotton in between them, and the flutes or indentations of the two rollers mutually locking into each other, they take the cotton more certainly. The lower roller is turned round by means of a bevilled wheel *l*, *fig*. 1, fixed on its spindle, which receives its motion from a similar bevilled wheel *k*, fixed on the extreme end of a spindle I, fixed perpendicularly to the axis of the main cylinder, and receiving its motion therefrom by a wheel *b*, which is turned by an endless screw *g*, cut upon the extremity of the spindle of the great cylinder.

The cotton is spread upon an endless revolving cloth, which is strained between two rollers, *a*, *b*, and is in constant motion, in the direction of the arrow in *fig*. 2. This motion is communicated to the roller, *a*, by means of equal cog-wheels *d*, *d*, which are connected by an intermediate toothed wheel, as shewn in *fig*. 2; M S is a grating, or frame of brass wire (shewn separate in *fig*. 4.) which is extended beneath the cylinder, and against this the cotton is urged by the action of the teeth of the cylinder, and the dirt, dust, and flue, escape through it. It should be observed, that the frame for the machine is closely boarded up on all sides, to keep in the dust and flue which is separated from the cotton. *Fig*. 5. shews the form of one of the lags, and the manner in which the teeth are disposed in it, so that the teeth in the several rows fall opposite the spaces between the teeth of the others: at *i* is a small slip of sheet iron, which stands up perpendicular to the face of the lag like the spikes, and is supported by a kind of wedge, or prop of wood, as seen in the section of the machine, *fig*. 2. These slips of iron run across the whole length: the teeth on the cylinder are disposed in a similar manner, and are provided with a similar iron plate. Their use is to retain the cotton which is worked in the machine from passing through too quickly, and escaping without being sufficiently worked by the teeth. The cotton is spread evenly upon the cloth *b d*, which being in constant motion towards the cylinder, carries the cotton along upon it, and delivers it between the two rollers *d*, *d*: these give it regularly to the cylinder, which is rapidly revolving in the direction of the arrow near A: its teeth take the cotton, and carry it round between the cylinder and the hood, working it between them, to open and unravel every knot or tuft of cotton, part of which gets formed by the action of the cylinder into a small roll at every one of the iron plates *i*, and this roll, by the motion of the cylinder, keeps revolving slowly round, so that every part of its circumference is successively subjected to the action of the teeth of the cylinder

as they pass by them. The plates upon the cylinder act in a similar manner, and when the cotton is thrown out finished at M, upon the floor immediately beneath the feet cloth, it has been opened in every part, so as to completely disentangle it, and the dust, cotton seeds, or any other extraneous matter, drops out through the wire grating, S M, upon the floor.

The opening machines used in some of the most improved mills, are provided with two cylinders revolving against each other, so that they resemble two of these machines put together, by which means the cotton is more completely worked in passing through them. The cylinders have then none of the plates fixed upon them, because they are unnecessary, and the spikes or teeth are arranged in a spiral line round the circumference of each cylinder, so that they do not in their motion fall behind each other, and therefore work and open the cotton more effectually. Another great improvement in this double cylinder machine, is the addition of a flue or trunk, which proceeds horizontally from the opening or mouth M, where the cotton is delivered, for a considerable distance, and in the bottom of this is a revolving cloth, which receives the cotton as it is thrown out, and conveys it away to the end of the room containing the machine. Here it falls out into a basket, in which it is conveyed away to the picking room. The flue or trunk at this point rises up, and leads into a chamber of considerable size, and from this returns by a small trunk to the back of the machine. The operation of this trunk is, that the wind raised by the rapid motion of the cylinders proceeds along this narrow trunk with a considerable velocity, and blowing along over the surface of the cotton, which is traversing slowly along with the endless cloth in the bottom of the trunk, it carries away the flue or small cotton with the stream into the large chamber above-mentioned. Here, in consequence of the large area which the air has to pass through, the current is very slow, and the flue subsides quietly on the floor of it, from which it may be taken up in considerable quantities every week, and is a valuable article for making candlewick, or to mix with inferior cottons for that purpose; whereas, if suffered to fly about in the rooms, as in the machine delineated, it does great injury to the work people, for this flue is taken into the lungs by the respiration, causing asthma, and pulmonary complaints: but in the improved machine, this flue is preserved for useful purposes.

The next machine, in the order of the cotton manufacture, is the *Carding machine*. This is shewn in *Plate* IV., where *fig.* 1. is a plan, *fig.* 2. a section, *fig.* 3. an elevation, and *fig.* 4, various parts to explain the action of this machine. It will not be amiss first to give a short idea of the nature of the operation to be performed by the machine. The card may be compared to a brush made with wires instead of hairs, stuck through a sheet of leather; the wires not being perpendicular to the plane, but all inclined one way in a certain angle. See *fig.* 4. of this plate, where D, C, are these sheets of leather for a pair of cards, and A, A, or B, B, represent the teeth or card-wires respectively belonging to each. Beneath is a view of one wire, insulated, shewing the two teeth, with their bend in the shank, or what is called knee-bend, by which they are inclined to the leather in the manner before mentioned. Now we may conceive that, cotton being stuck upon the teeth of one of these cards, another may be applied to it, and combed or scraped in such a direction as to strike the cotton inwards upon the teeth, rather than tend to draw it out. The consequence of a repetition of the strokes of the empty card, in this direction upon the full one, is a more equable distribution of the cotton upon the surface of the card-teeth; and in doing this, the fibres are combed and laid straight. Then if one card be drawn in an opposite direction over the other, it will, in consequence of the inclination of its wires, take the whole of the cotton out of the card, whose inclination is the contrary way. In this mode, the operation was formerly conducted by sheets of cards nailed upon boards, which were worked together by hand. To explain how the carding machine imitates this process, we must return to the figures, in which A A is a large cylinder, turned rapidly round by an endless strap on the pulley R. The surface of the cylinder is covered with cards, the sheets of leather for which are glued or nailed on in stripes or sheets parallel with its axis, and disposed in such a direction, that when it revolves in the direction of the arrow, the teeth upon it go with their points forward, so that if a lock of cotton was held against them, it would be drawn inwards upon the teeth. The cylinder revolves under an arch C C, lined with the same kinds of cards as shewn in *fig.* 2; the teeth disposed to meet those of the cylinder. This arch of cards is supported on two iron arches, fixed on each side of the cylinder. These iron arches or bridges have spikes on them, on which the several pieces, lags, or flats which compose the arch are fastened; exactly the same as described in *Plate* III. of the opening machine.

One of the iron arches is shewn at E E, in *fig.* 2, but is not drawn off its full breadth, because it would have concealed the surface of the cylinder from the sight; but in *fig.* 1. they are seen at C C, and in *fig.* 3. at *f f*. The card-teeth on the cylinder, and those beneath the arch, do not touch each other, but work as close together that a half crown can be put in the space between them without touching, and they are made very accurately circular, that they may always accurately preserve the same distance between.

B is a second cylinder of cards, the teeth meeting the first, as the figure shews. This cylinder revolves much slower than the first, its motion being taken from a small pinion, *t*, *fig.* 1, on the end of the axis of the great cylinder. This works a wheel, situated on a stud or pin *s*; which has also a pinion fixed to it, working a wheel *t*, fitted on another stud, and this carries a small pulley *v*, which communicates by an endless strap with a pulley, E, fixed on the end of the spindle of the small cylinder. As the whole of this train of wheel-work consists of small wheels turning large ones, it is plain the motion of the cylinder, B, must be very slow. On the opposite end of its axis is a bevilled wheel W, working another upon the end of an axis *h*, which has, at its opposite extremity, a pinion, turning a face or contrate wheel *i*, which is on the axis of the fluted feeding rollers between which the cotton passes, and is delivered to the cylinder. The cotton is, as was before described of the opening machine, spread out upon a feeding cloth D, which traverses constantly round two rollers *k* and *l l*, one of which is turned by a pinion from the feeding rollers by means of an intermediate wheel at *k*. A small heavy roller, or cylindrical weight, is put upon the cloth beneath, as shewn at *f*, *fig.* 2, and, by its weight, always keeps the cloth to its proper tension, preserving a flat surface above, for the cotton to be spread out upon, and then advancing with the cloth, it is thrown in between the fluted feeding rollers, which deliver it gradually and equably to the cylinder, which carries it round, and works it against the cards fixed withinside the arch. In this process it becomes very equably distributed over the teeth in the cylinder, and gets carded in so doing. The cotton continues in this manner hanging sometimes in the teeth of the cylinder, and sometimes in those of the arch, but advancing slowly from one tooth to the next, till it has passed clear through the arch, and then it comes to the small cylinder B, which, as before-mentioned, is revolving slowly, in such a direction that its

ſurface moves the ſame way as the cylinder, but much ſlower, and its teeth meet the teeth of the cylinder. Now, as before ſtated, it is the property of two cards meeting each other to diſtribute the cotton between them; therefore, the teeth of the cylinder B, having no cotton upon them, receive a full half of what is upon the teeth of the cylinder A, and as it conſtantly turns round, and bringing up freſh empty teeth, which in their turn take away the cotton from the great cylinder in a conſtant ſtream, and would ſoon empty it, but that it is ſupplied again with raw cotton from the feeding roller. The cotton taken up by the cylinder B, proceeds with it beneath, till it comes to the oppoſite ſide, and then it is removed by the *taker off*. This is a rod or iron bar *g g*, ſituated parallel to the axis of the cylinder, and cut on the lower edge with fine teeth like a comb. It riſes and falls parallel to itſelf, by being united to two rods, K, which are guided by ſliding through ſmall holes made in two ſtandards ſhewn in *fig.* 2, and the lower ends of theſe rods are jointed to two cranks *e, e, fig.* 3, formed on a ſpindle, which is turned by a pulley *p*, with an endleſs ſtrap from a pulley, S, fixed on the main axis, cloſe behind the great pulley R. Now by the motion of theſe cranks, the rod *g* riſes and falls, and at the ſame time moves a little to and from the ſurface of the cylinder B: indeed it deſcribes a kind of ellipſis, and being ſo contrived by the direction of the motion of the cranks (cauſed by croſſing the ſtrap which works them), that it is deſcending at the time when its edge is neareſt to the cylinder, and ſcrapes downwards againſt, or rather between the teeth thereof, and in conſequence removes the cotton from them the whole length of the cylinder at once: and the motion of the crank is ſo quick, that by the time this piece of cotton, ſo detached from the teeth of the great cylinder, has moved round with the cylinder, B, as much as its own breadth, the crank makes another ſtroke, and, in conſequence, the ſecond piece detached from the teeth adheres to the firſt: the third adheres to the ſecond, and ſo on. The cotton is thus *ſtripped* or ſkinned off the cylinder, B, in a continued and connected fleece. The diſpoſal of this fleece conſtitutes the only difference between the breaking and finiſhing card. In the former it is received upon a plain cylinder, about half the ſize of the great cylinder A A, which is turned round with a proper velocity by an endleſs cord from a pulley on the axis of the cylinder B, a ſmall roller reſting lightly upon the top of this cylinder with its own weight, and by its preſſure cauſes the fleece to lap regularly upon the cylinder, which continues to turn until it has made 15 or 20 revolutions. The fleece, being then broken off, forms a ſmall fleece, conſiſting of 15 or 20 thickneſſes, called the lap, which is carried to the finiſhing card, and treated exactly as the raw cotton was at firſt. The advantage of this method of treating the cotton has been explained, in a preceding part of this article, to conſiſt in the great equality thus produced in the thickneſs of the lap, which being fed to the finiſhing card will produce an equable and regular ſliver therefrom, and on this circumſtance the perfection of the ultimate thread very intimately depends.

... is that which is repreſented in *Plate* IV.

linder, as we have deſcribed, is gathered up into a tin funnel marked *m* in *fig.* 1, and *l* in *fig.* 2: it then paſſes between a pair of rollers *m n*, which compreſs and flatten the fleece in its contracted ſtate into a pretty firm and connected ſliver or band, and deliver it into a can *n*. Theſe rollers are ſituated upon a ſpindle extending acroſs the frame, and turned round by a pulley upon the end of it, which is connected by an endleſs band with the pulley E, upon the ſpindle of the cylinder B. By theſe means the cotton is reduced from the wool to a fine regular and even ſliver, which is conveyed away in the tin can to the drawing frame, which we ſhall ſoon deſcribe.

The carding engines in many mills are provided with ſmall cylinders, known among the workmen by the technical term of *urchins*. Theſe are covered with cards, and revolve, ſo that their teeth act with the teeth of the great cylinder, through proper openings left between the top lags of the arch. Theſe ſmall cylinders are turned round ſlowly by proper bands and pullies from the main axis. Theſe urchins are ſituated in pairs, one of which operates to take the cotton off the great cylinder, in the ſame manner as deſcribed of the cylinder B; but inſtead of being provided with a taker off, to ſtrip the cotton from its ſurface, it runs cloſe to the other urchin, of ſimilar dimenſions to itſelf, but turning with a different velocity, and the teeth meeting, ſo as to take it off the firſt urchin. This ſecond urchin, having thus become charged with cotton, delivers it again to the great cylinder. The object of this contrivance is to obtain a more perfectly equal diſtribution of the cotton upon the ſurface of the cylinder, at the ſame time the urchins tend, by giving the cotton to the cylinder in a new direction, to work it more, as they prevent the cotton paſſing ſo quickly through the machine. The employment of urchins does not ſeem to afford any very great advantages, and it is not a very general ſyſtem. When an urchin is applied to the lower part of the cylinder, immediately beneath the feeding roller, it is called a *tummer*: in this caſe it takes the cotton from the feed rolls, and gives it to the great cylinder as it revolves. The great cylinder of a carding engine, as well as any other part where the flue can eſcape, ſhould be carefully incloſed by a tin plate, or thin boarding, to prevent its eſcape into the room, where it does great injury to the work people, producing an irritating and inceſſant cough, which is exceedingly hurtful, as well as the pernicious effects of ſuch extraneous matter being received into the lungs. Carding engines have been uſed with two great cylinders, ſurrounded by a multitude of ſmall urchins, in the ſame manner as thoſe uſed for wool. (See Woollen *Manufacture*.) Theſe, having two cylinders, card the cotton ſufficiently at one operation, without uſing a breaking card. The method is not near ſo perfect, becauſe the equality and regularity of the ſliver, produced by doubling the lap of the breaker 15 or 20 times, cannot be ſo completely attained by any other means, but leaves this equalization to be performed in the drawing frame. The double card, however, anſwers very well for coarſe goods, and ſaves a great deal of attendance in conveying the lap of the breaking card to the feeding cloth of the finiſher. Since the time that the drawing for *Plate* IV. was made, the cotton manufacturers have almoſt univerſally adopted what were at that time only partially employed, viz. caſt iron frames for the carding machines, and iron circles for the cylinders, which are covered with lags of the beſt

will ſometimes do in wooden frames, and thus deſtroy the card teeth very ſoon, as well as produce leſs perfect work. The ſame remark applies to all the other cotton machines, and, in point of expence, caſt iron is far cheaper than wood

when a number of the same part are to be made, so that they can all be cast from the same pattern: in point of stability and duration no comparison can be made; and when the mill is built fire proof, the safety from fire is not a trifling advantage, as it saves the manufacturer the heavy expence of insurance, or, what of course is nearly equal, the risk of losing his property by fire.

The drawing frame comes next to be described. *Plate* V. *fig.* 1. is an elevation of the machine, and *fig.* 2. is a plan of what is called a drawing frame of four heads, which is, in fact, a system composed of four distinct machines of exactly the same construction, but arranged on one frame, in the most convenient position to be used successively. *Fig.* 3. is a front view of one of the heads or separate machines drawn detached; and *fig.* 4. is a section answering to it. In *fig.* 1. A represents a cluster, consisting of four of the cans brought from the carding machine: the four slivers from these are passed through the rollers of the machine, and united into one sliver, which is received in the can C, the machine having drawn it out, and extended it to four times the length of the others; it is therefore the same size as any one of them. The construction of the rollers is explained by *fig.* 3, and also the figure at the left hand end of *fig.* 2, in which *a b* represents a live and dead pulley, upon the spindle of the principal, or front roller, by which it receives its motion from an endless strap. This roller is shewn, in *figs.* 2. and 3, to be double, that is, it has two lengths or acting rollers upon it, each of which receives two distinct slivers from the cans *l l, l l, fig.* 2. In *fig.* 4. these two lengths of rollers appear like one, being behind each other, and exhibiting the circle marked *a*, the other circle described within this being the neck between the two lengths. This roller has another, marked *b*, placed directly over it, the pivots of which are retained in a vertical notch in the frame, and immediately above the pivots for the lower roller, as is shewn in *fig.* 1; so that the whole weight of the upper roller rests upon the surface of the lower one, the bearings or notches in which its pivots are received being only to guide, not support it. Another pair of similar rollers, *c d*, are situated at a small distance from the former, and receive their motion by pinions *c, d, figs.* 2 and 3, which are fixed on the pivots of each respectively, and are connected by an intermediate wheel, *e*, fitted loosely on a stud, in the manner very plainly shewn in *fig.* 1, which also expresses the grooves or notches in the standards; in these the pivots of the rollers are retained sideways upon one another, but, as before mentioned, the upper one rests upon the lower one. A small cross bar, *i, fig.* 4, extends from the pivot, or neck, of one of the upper rollers, *d*, to that of the other one, *b*; and from the centre of this bar an iron rod, with a heavy weight, *f*, at the lower end of it, is suspended by a hook formed at the upper end; so that this weight, as well as the weight of the upper rollers themselves, press the upper rollers, *b, d*, upon the lower ones, *a, c*, and thus the sliver of cotton, *g*, which passes between them, is held very firmly down on the flutes in the surface of the lower roller, and cannot slip between them. The wheel *c, figs.* 2 and 3, which is fixed upon the pivot of the first roller, is much smaller in diameter than the wheel, *d*, upon the pivot of the back roller, to which it gives motion by the intermediate wheel *e*; therefore it follows, that the motion of the front rollers, *a, b, fig.* 4, will be as much quicker than the back roller *c d*, in proportion as the wheel, *d*, is larger than the wheel, *c*, which gives it motion; that is, the number of revolutions they will respectively make in any given space of time (as a minute for instance) will bear that proportion: but the back roller, *c*, (as shewn in *fig.* 4.) is much smaller than the other. The velocity of its circumference will, therefore, be slower than *a*, in a still greater proportion than the proportion of the two wheels; and the proportion is such, that the roller, *a b*, will, or ought to, draw four times the length of cotton through them which the back pair, *c d*, will permit to pass in the same time. The four slivers, therefore, being introduced from the cans *l, l, l, l, fig.* 2, between the back rollers *c, d, fig.* 4, and pressed with such force upon the flutes of the lower roller *c*, that they cannot slip through them, and the other pair of rollers, *a b*, holding the slivers in the same manner at another part, the consequence of their different velocities is, that as the front rollers, *a, b, fig.* 4, move so much quicker, they draw the sliver forwards faster than the back rollers will suffer it to come; it must be drawn out, or extended in length, between the two pair of rollers, in proportion to their relative velocities, which, as before-mentioned, is the same as the proportion between the wheels *c, d, figs.* 2 and 3, communicating the motion from one to the other, multiplied by the proportion between the diameter of the two rollers, *a* and *c, fig.* 4. The four slivers, after passing through these in two distinct pairs, are all drawn together through a tin funnel *f, fig.* 2, by means of a pair of rollers, the upper one, *i*, of which merely presses upon the sliver lightly by its own weight, and delivers it into the can *k*: the lowest of this pair of rollers receives its motion from the pinion, *c*, on the end of the spindle of the main, or front rollers, by means of an intermediate wheel, *g*, fitted upon a stud or pin in the frame, and turning a pinion, *h*, fixed on the extremity of the spindle of the lower of the two rollers. These pair of rollers do not draw or extend the cotton, their velocities being accurately adapted to take up the four slivers as fast as they come through the others in two distinct pairs, and by drawing them through the funnel, *f*, to unite the four into one, and the slight pressure of the roller compresses them into a firm and connected sliver, which, though compounded of four, is only the same size as any one of the four put in, because it is drawn out to four times the length, and the effect of the machine has only been to straighten and lay the fibres parallel to each other; for the motion the drawing produces among them, always tends to extend each individual fibre to its full length: and it is necessary to unite several slivers together, or the drawing would reduce the sliver to such a small size, that it would not bear sufficient extension without separating and breaking across. The plan, *fig.* 2, shews the disposition of four distinct heads, or sets of rollers, A, B, C, D, all fixed upon one iron frame, E, the upright of which is shewn in *fig.* 1. D is the first head, or that through which the slivers from the carding engine in the cans, *m, m, m, m*, are first drawn and united into one, which is delivered into the can *n*. In this head six cans, or ends, are shewn entering at once, in two sets of three each, and are all united into one, which will, therefore, if the rollers only draw four times, be rather thicker than those put in; but the number of ends put in, as well as the *draught* of the rollers, is optional: and as the command of the cotton-spinner, who alters them for different kinds of cotton, or different kinds of yarn to be spun as he finds best, having the means of changing the pinions for others of different sizes. It is plain that the can, *n*, will be filled with the sliver in one-fourth or one-sixth of the time that the four or six cans, *m m*, will be exhausted; and, therefore, it will furnish four cans, or ends, to the second head, *c*, which are placed at *o*, and drawn into one at *p*. Four of these, when filled, go to *q*, and are drawn into one by the head B, and delivered into *r*, which is taken to *s*, and by the head A, delivered finished into the can *k*, in which it is carried to the roving frame. The several heads, as the figure shews, are

reverfed, with refpect to each other, on the frame, to avoid the neceffity of carrying the cans round to the oppofite fide of the frame in paffing from one head to the next. Being thus reverfed, that is, the fliver of one moving in a contrary direction to that next it, it requires the ftraps, which turn the feveral live and dead pullies, and which all come from one common axis, on which as many drums are fixed, to be alternately croffed, and put on in the common manner.

The drawing frame in *Plate* V. has now (1812) been drawn fome years by a gentleman at Manchefter, fince which, the cotton manufacturers have very generally adopted a method of ufing three, and fometimes four pairs of rollers, inftead of only two pair in each head: by this means, they draw the cotton at two or three times, and, by extending it only a fmall quantity at each, it is found to draw much more equably than by taking the whole draught at once. The conftruction of one of thefe heads will be readily underftood, by examining a figure in the drawing (*Plate* IX.) of the fpinning-frame we fhall fhortly defcribe, which drawing the writer of this article made from one of the fpinning-frames in one of the moft complete cotton-mills in the kingdom. The rollers ufed in this fpinning and the drawing-frame are fo nearly alike, that one may be very well underftood from a defcription of the other.

The Roving-frame.—The preceding machines having prepared a fliver, of which the fibres are laid parallel, it is neceffary to reduce this fliver to a convenient fize for fpinning into a fmall thread: but to make a fufficient extenfion to effect this reduction, it is neceffary to give the fliver a flight twift as it is drawn, that it may have fufficient cohefion to undergo the fpinning.

The preparation of fuch rovings as fhall be perfectly regular in fize, and have an equal quantity of twift in every part, and which fhall be exceedingly foft, is a moft effential point in cotton-fpinning. As it is impoffible to correct thefe imperfections in the fpinning, they will be given to the thread. A great number of different conftructions of roving-frame have been in repute, at different periods, among cotton-fpinners; but it is only lately that by a machine, called the double-fpeeder, it has been brought to perfection. The old roving-can frame, firft introduced by fir R. Arkwright, is reprefented in *Plate* VI., which was drawn when that machine was much more extenfively ufed than it is now. The figure immediately beneath the title of this plate is a plan of the roving-can frame, and the figure below is a front elevation: in thefe, A is a horizontal beam fupported by ftandards at each end, and carrying the feveral heads of rollers, and is therefore called the roller-beam. The machine contains four heads or frames of rollers, each of which receives four ends or flivers from the cans, D, D. See alfo the fection in the corner. They enter two together between the back roller *c*, and are drawn out between them and the front rollers, *b*, *d*, to the proper degree of finenefs, but which varies with the quality of the yarn which is to be fpun. The fliver, after paffing through the rollers, is received into a tin can C, through a fmall funnel, N, at the mouth thereof. The can is fupported on a pivot at bottom, and is kept in rapid motion by a band, working on a pulley fixed at the bottom of the can. The neck of the funnel, N, is guided by a collar, to keep the can fteadily upright, as it revolves. The rollers of the machine are the fame as thofe of the drawing-frame: they are turned by endlefs ftraps upon the pullies, *p*, of the front rollers, coming up from fimilar pullies on an horizontal fpindle extended beneath the machine, through its whole length, and receiving motion by a live and dead pulley, E F, from the mill. The fame fpindle has pullies upon it, which, by means of bands, actuate the pullies on the bottom of the can. Thefe bands are of courfe conducted over pullies, to change their directions, from the vertical pullies on the fpindle of E F to the horizontal pullies on the bottom of the cans; but thefe are not fhewn in the drawings. Each of the bands drives two cans, paffing round the pullies of both. The cans are made with a door, to open on one fide, for taking out the cotton-roving, which falls into them from the rollers; and this door is kept clofed by a ring, which fits upon the outfide of the can, and keeps the door fhut, when pufhed down to the largeft part of the cone; but when lifted up to the top, as fhewn near N, the door can be opened, and the contained cotton taken out. L is what is called the clearer: it is a piece of wood placed over the top-rollers, and preffing gently upon them; its ufe is to prevent any part of the cotton *lapping*, that is, adhering to the roller, and being carried round with it, fo as to wind it up, inftead of drawing it through. The manner of action, in this machine, is eafily gathered from the defcription: the flivers pafs two together through the rollers, and are reduced or drawn out therein to the proper degree of finenefs; then falling into the funnels, N, of the revolving cans, they are, by the rapid motion thereof, twifted round; becaufe the centrifugal force difpofes the cotton to lie round the infide of the can in a regular coil, forming as it were a lining of cotton to the whole of the interior furface; and by this means the end of the roving becomes in a meafure attached to the can, and is twifted round by its motion, fo as to form a coarfe loofe thread, with a very flight twift, and a very foft and open fubftance. The cans, when they have been in motion fuch a length of time as the attendant knows, by experience, they will be full of cotton, the ring is raifed up, and the door opened to take out the roving, which is put into a box, and carried to a fimple machine, called the winding-block: fee the figure at the right hand corner of the plate. In this figure, which is an elevation, the box, containing two piles or coils of the roving, is plainly feen: juft above it is a cylinder of confiderable fize, mounted upon a proper fpindle, which is turned round by means of a winch: *k*, *k*, are two fmall bobbins, mounted on a wire, and receiving the end of the roving; they reft with their weight upon the furface of the great cylinder, and are by the motion thereof turned rapidly round, fo as to wind up the roving very quickly on them. The rovings are conducted through holes in a ftrip or ruler of wood, which is moved flowly backwards and forwards, to lay the cotton equally on all parts of the length of the bobbin, and make a cylindric figure to the furface of the cotton wound upon it. It is the neceffity for this winding of the cotton upon bobbins by a feparate procefs, which is the greateft objection to the roving-can frame, becaufe the tender roving is damaged by every operation it undergoes, *viz.* removing it from the cans, and winding it upon the bobbins, which muft be done preparatory to the fpinning. Another objection to the roving-can frame is the uncertainty in the manner of twifting; becaufe, when the cotton applies itfelf to the interior furface of the can, by the centrifugal force, it occafions a ftretching or draught on the roving, tending to lengthen it out before it is fufficiently twifted to make any refiftance to the flighteft draught. This would occafion no inconvenience, if the degree of draught or extenfion thus occafioned was conftant, and uniformly the fame; but this is not the cafe: for it conftantly happens that the roving, by gradually gathering from the circumference toward the centre of the can, in the manner of a fpiral, and when it arrives in the centre it coincides with the axis of the can, and of courfe, as no centrifugal force operates to draw it out in length, it merely twifts it

round. In consequence of these irregularities in the action, which are constantly happening, the rovings thus produced are always full of thick and thin places; for when the cotton lies close at the inside of the can, it is considerably stretched by the centrifugal force, and becomes thinner and longer, and with less twist in any given length; but when it happens to fall in the centre of the can, it is of a larger size, and of a more rapid twist: but the quantity of these irregularities is very uncertain, because, even when the end of the roving, where it rests upon the coil of it, which is settled in the bottom of the can, is in the centre of the can, it is to be presumed that no draught will take place; but this is not certain, because the roving may swing out into a belly, and by its vibration will occasion some draught, though not so great as in the first instance. For these reasons, the roving-cans are not found to produce such perfect rovings as many other methods, and they are generally laid aside. Sir R. Arkwright saw these defects at first, and in his earliest machine devised a pair of rollers to be placed in the mouth of the funnel of the can, which were, by very ingenious mechanism, kept in constant motion, with such a velocity as to gather the cotton sliver regularly into the can, as fast as it was delivered by the drawing-rollers. By these means the sliver was held between these rollers, and, from their revolution with the can, received a determinate quantity of twist for every given portion of length. The difficulties of this were very great, to cause the rollers, in the mouth of the can, to take the sliver with the exact velocity required, as fast as the upper rollers delivered it; and even when this was accomplished, the objections we have pointed out would in some measure take place within the can; and after all the operation of winding the rovings upon the bobbins, preparatory for the spinning-frame, by the winding-block, is certain to do them injury, stretching and extending them improperly. The next improvement in roving was the use of *skeleton-cans:* these are light frames of iron, revolving on vertical pivots, in the manner of the cans themselves, in *Plate* VI. Within each of these skeletons or frames a common tin can is placed, and revolves with them, receiving the rovings as we have above described. These cans, when full, are removed to a machine called the stretching-frame, which gives them rather more twist, and extends them still farther in length, at the same time winding them on bobbins, which are called cops or coppins, being bobbins with only one end, the other end being a point, so that the cop in figure resembles a *fir-ball*, or pine-apple. The construction of the stretching-frame is the same, except in its proportions, as the mule: we must, therefore, defer the description of this method of roving till we have explained the mule, when we come to speak of the spinning process. Many mills, where cotton is spun on the most improved and economic system, have adopted a method of roving altogether upon the stretching-frame, producing rovings at once from the slivers of the drawing-frame; and this method is found to succeed very well, and be a great improvement upon the method of employing the roving-can frame. We shall next describe a roving machine, called by the workmen in cotton-mills,

The Double-speeder.—This is a roving-frame, which is extremely perfect in its operation, making better work than any other method: it is an improvement upon some machines made by sir Richard Arkwright, at a very early period of the cotton manufacture; but the improvements are so essential and ingenious, that the maker or makers of them deserve the whole credit. Who is entitled to the invention of these improvements, we have not been informed; but we have seen machines, made by Samuel Smith of Ramsbottom, near Bury in Lancashire, which were extremely good. The drawings, entitled *Plate* VII., or roving-frame, *Plate* I. also *Plate* VIII., *Cotton Manufacture*, which we have given of this machine, have, like those preceding it, been made before the improvements were brought to the perfection they have since attained; and though the machine has the same parts, the proportions are such, that a machine, made exactly after them, would not operate so completely as those made by Mr. Smith, to whom we refer cotton manufacturers, who wish to adopt such machines, rather than attempting to make them from the drawings in our plates. They will serve, however, to illustrate the principles and mode of their construction. *Plate* I. is a horizontal plan of the machine; and *Plate* VIII. is an elevation, taken in front of the machine. In this figure, A represents the live and dead pulley, which communicates motion to the whole: it is fixed on a short axis, on the extreme end of which is a pulley, B, which communicates, by an endless strap, with another pulley, D, on an horizontal axis *g*: and this has at the end a bevilled wheel, which turns another on a vertical axis *k*, at the lower end of which a conical drum or barrel, H, is fixed; and beneath this it is formed cylindrical, to receive a strap, which passes round the pullies, *h*, *h*, on the lower ends of the several spindles, I, I, I; and then returning to the drum again, the ends are united, and form an endless belt, which runs round the whole, turning them all at once with the same velocity: *l*, *l*, are small rollers, situated at intervals between every two pair of the spindles; these bend the strap out of the straight line, and thus cause it to press against the pullies, *h*, *h*, of the spindles, and apply to a sufficient portion of their surface, to turn them round. This is very plainly shewn in *Plate* I.: each of the spindles, I, I, I, has at its upper end a forked piece of iron, *q q*, fixed on, which is called the flyer; and one of the forks is made tubular, to receive the roving as fast as it is twisted by the motion of the flyer, and convey it to the bobbin, which is fitted quite loosely on the spindle. The cans from the drawing-frame are, as shewn in *Plate* I., set behind the machine; and the slivers are drawn through a double pair of drawing-rollers, turned by means of a train of wheel-work from the main spindle, bearing the live and dead pulley, A, *Plate* VIII. The slivers pass singly through the rollers, and are drawn out or extended singly; they then pass forwards, and two are drawn together through another double pair of drawing-rollers, the front pair of which are shewn at *c*, *c*, in *Plate* VIII.: *a*, *b*, are the pair of wheels which turn them from the main spindle; *f*, *f*, the weights; and *e*, the clearer. These rollers deliver the sliver to the flyers, at the top of the spindles, I, I, where it first passes through a collar, or eye-hole, *r*, formed on each of the flyers, exactly in the centre of the spindle, and thence it passes through the tube, *q*, before mentioned, to the bobbin *p*: the two back pair of rollers extend or draw out the sliver twice; then the two front pair, which are shewn in *Plate* VIII., draw it again, and the spindles twist it once for every inch and a half. The tube of the flyer, running swiftly round the bobbin, lays the roving upon it as fast as the rollers deliver it out. The bobbins, *p*, *p*, are constructed so as to rise and fall upon the spindles, I, I, that they may lay the roving, coming from the end of the tube *q*, regularly upon the length of the bobbin. This is done by an horizontal bar, or rail of wood, N, which has holes through it, to admit the several spindles I, I, I, and the weight of the bobbin *p*, *p*, rests upon it; so that when it rises and falls parallel to itself, it takes the bobbins with it, elevating them as at *p*, in *fig.* 2. In this position, the bobbin receives the roving, and winds it on the lower part of them; but as the machine continues to wind, the rail with the bobbins gradually sink down; so that every turn of the roving falls close to, but not upon, the former turn, thus disposing it equally

through all the length of the bobbins; and when they have descended to the lowest point, and the bobbins have been filled up to the top, it rises gradually up again. This ascending and descending motion of the rail and bobbins is thus produced: the vertical axis of the conical drum, H, has a bevilled wheel upon it beneath, (not seen in the figure,) which turns another, *s*, fixed on an horizontal spindle; at the other end of which is a pinion, *t*, turning a toothed wheel upon the end of an horizontal axis *v*, which carries a bevilled wheel *w*, turning another, on a vertical axis *y*, which has an endless screw at the upper end, turning a wheel, R, upon a long horizontal axis, which has two pullies or wheels, M, on it: each of these receive a chain, which chains, at the lower end, support the rail N; and when the chains wind up, they elevate the rail with the bobbins; but when they let down the chains, the rail, N, descends. The reversion of the motion which is necessary to effect this, is done by the wheel, *w*, having another bevilled wheel, exactly similar to it, fixed on the same spindle *v*, and very near to the horizontal wheel worked by it: therefore this wheel, on the spindle *y*, being made to work either in one of these wheels or the other, will, in consequence, turn round one way or the other, elevating or depressing the rail N, and the bobbins accordingly: the lower pivot of the vertical axis, *y*, is supported in a horizontal lever, which is, by the motion of the rail N, when it arrives at the highest point of its movement, moved to bring the wheel to work in the opposite bevilled wheel, on the spindle *v*; and then it turns M in a contrary direction, bringing the rail, N, down again; and when it arrives at the lowest point, the bevilled wheel is again thrown in gear with the wheel *w*, and being thus turned in a contrary direction, it raises the bobbins up again. The connecting parts by which the bevilled wheel is shifted every time it is necessary to reverse the motion, are not shewn in the drawing, but they may easily be imagined: *x, x*, represent the weights which are suspended from the upper front rollers, the same as those used in the drawing frame.

What we have hitherto explained of this machine is the original roving-frame, tried by sir Richard Arkwright on finding the defects of the roving-can frame. The objections to this machine in its original state were, that the bobbins, when they became filled with roving, required so much more force to turn them round, in consequence of their superior weight, than when they were empty and unloaded; that they acted, to stretch or draw out the rovings, in the same manner as the can before mentioned; for the revolution of the flyer *q*, round the bobbin *p*, gives the twist to the roving at the nose or socket, *r*, of the spindle; and if the bobbin was stationary, it is evident the roving would be lapped round it once for every turn of the spindle: but this would require the roving to be delivered out by the drawing-rollers much faster than they are intended to do. The consequence of the bobbin being fixed would be, that the roving must be stretched out to a sufficient length to supply as much length as the motion of the end of the tube of the flyer, *q*, requires. Now suppose, instead of the bobbin being fixed stationary, it is only retained by the friction of resting its lower end upon the rail N, the roving will then only be stretched with as much force as will drag the bobbin round after the flyer, with as much velocity as the difference between the quantity of motion of the end of the flyer, and of the roving, as delivered out by the drawing-roller: this difference will enable the bobbin to take up all the roving as it is made.

Now it is plain, that to drag a heavy bobbin thus about, must require more strain on the roving than for a light bobbin, and in consequence, it is always drawn out smaller towards the time when the bobbin becomes filled. This is particularly hurtful, because the roving, which will afterwards spin to the greatest advantage, is so extremely delicate as not to be able to bear the slightest strain; and if the machine requires it to undergo any strain, it must be twisted harder, and this will render it less fit to undergo the spinning. The manner in which these objections are obviated in the double speeder, is by introducing machinery which will give motion to the bobbin, and turn it round with such a velocity, that it will take up the roving just as fast as it is produced; but it is necessary, in effecting this, that the velocity shall be altered every time the bobbin has a new layer or roving beginning to be lapped upon it, because every time this happens the bobbin increases in its diameter, and must therefore move in such a manner as will cause its acting circumference to keep the same velocity at all times. To describe this see *fig.* 1, where for every bobbin, *p*, a small pulley is shewn resting upon the rail N, the spindle passing through its centre. The bobbin, which rests upon it, has a hole made in the underside of it, and the wheel having a pin entering this hole, so that the wheel, being turned round, compels the bobbin to turn with it. An endless strap, *n*, passes round all these wheels, having binders *o*, or pullies, which bend the strap, and cause it to act upon a sufficient part of the circumference of the wheels, to take such hold as will carry them round. This endless strap also passes round a cylindrical barrel L, fixed upon the upper end of the conical barrel K, which is of the same dimentions as the barrel H, but inverted, that is, the large end of the barrel, H, is opposite the small end of the barrel K. This being the case, an endless strap, *m*, which is passed round both, will communicate the motion of one to the other, and if the axes of the two cones are parallel, the strap will preserve the same tension, whether it works at one or other end of the two cones, because whatever quantity the strap will be loosed by acting on a small part of one cone, it will at the same time be tightened, or taken up as much, by being upon the larger part of the opposite cone; but it is plain that this alteration of the acting point of the strap will produce a correspondent alteration in the velocity of the motion of the cone K, which is turned round by the strap. Thus, the motion of the cone, H, is equable and uniform in velocity, being actuated by wheel-work from the principal spindle of the machine. Now suppose the strap, *m*, at the top of the cone H, then it acts with a small diameter upon the large diameter of the top of the cone K, which therefore moves much slower than H. Now by shifting the strap lower down upon the cones, the acting diameter of H is increased, while K diminishes till they come to a point, where they will be of equal diameter, and of course have equal velocities; but beneath this point, the diameter of K will be the smallest, and of course its velocity will be greater than H, which actuates it. When the machine is first put to work, and the bobbins are all empty, they must move slowly, because they are required to follow the flyer round, so that they will only take up as much as the rollers produce; for if they were stationary, they would gather up, as before-mentioned, as much as the motion of the end of the flyer, therefore, within certain limits, the slower the bobbin moves, the more it will take up; and if it moved as quick as the end of the flyer, it would take up none at all. For this reason, at first starting the machine, when the bobbins are all empty, the strap, *m*, must be at such a height up the cones, that the bobbins will have their proper velocities to wind up the rovings as fast as they are required, and the bobbins rise or fall, as is requisite, to lap the roving equably upon them; but having thus covered each bobbin with one layer of roving, and beginning to wind another layer upon it, the acting diameter of the bobbin is

increased, and it must therefore turn so much quicker, (that is, it must make so many more turns in any given space of time,) as will cause the increased acting circumference to wind up no faster than it did when it was smaller. This seems, at first hearing, to be a paradox, that it should be requisite to turn round quicker to wind up no faster upon the increased radius; but it is to be considered that, by the bobbin being moved quicker, it follows and keeps nearer the end of the flyer tube, and therefore winds up less, because the quantity which the bobbin will take up depends on the difference between two motions, that is, the difference between the flyer and that of the bobbin which follows it. This increased velocity of the bobbin is occasioned by the strap, *m*, being, at the time when the bobbin is filled with roving up to the top, or down to the bottom, depressed or shifted down on the cones a small quantity, which occasions, as before-described, a small increase in the velocity of the motion of the cone K, and of the bobbins. The depression of the strap is performed by a lever, which takes hold of the strap with a fork, and when urged, leads it up or down upon the conical barrel. This lever is actuated by a snail, upon the axis of which is fixed a ratchet-wheel, turned round by proper clicks, levers, and other connecting mechanism, one tooth every time the bobbins and rail, N, begin to ascend and descend, or, in other words, arrive at the extreme limits of their motion. Then the snail acting on the lever depresses the strap a sufficient quantity, to produce the alteration of velocity required.

Thus, as the bobbins increase in diameter by the addition of successive layers of the roving, they adapt their velocities to that increase, and taking it up just as fast as it is produced, and no faster, so that the roving, as it passes from the end of the flyer tube to the bobbin, is never stretched, and never becomes slack. The intelligent mechanic will readily percieve that this is practicable, but at the same time he will be sensible of the accuracy requisite in the adjustment of such a machine to its work, and the difficulty of making this adjustment for different sizes of roving. This, perhaps, is the only bar to its general use, that it requires a skilful mechanic to attend and take charge of it, because every different size of roving, which is made in it, will require a different rate of increase or decrease of motion, by means of the strap *m*, for a large thread causes the diameter of the bobbin to increase more rapidly than a small one, and therefore the quantity of shift which the strap, *m*, makes every time on the two cones K, H, must be determined by the size of the roving, as is also the height at which the strap shall stand when the machine is first set to work, and the bobbins are all empty. These adjustments are made in the lever snail, and other connecting mechanism, which are omitted in our plates. We have attended for a long time to the action of several double speeders of this kind, made by Mr. Smith, and adjusted by him, which performed their work in the most perfect manner, making a roving so loose and soft, that it would part with the slightest force, but at the same time as regular and even as possible, and the yarn spun from it was greatly superior to any which could be produced from the same material by any other means we have seen. We venture to prognosticate that the general introduction of this machine, when a sufficient number of managers are instructed how to make it work properly, will be a great improvement of a most essential department in cotton-spinning.

The rovings, thus prepared on bobbins, are carried to be spun, either, as before explained, in the water-frame, or mule. We shall describe the former first: it is constructed in two very different forms; and though in both the operating parts are the same, the machinery which actuates them are very different. One is called the water frame, being the original spinning frame, as first constructed by sir Richard Arkwright, whilst the other is a more modern construction, and is known by the name of the throstle frame. Their comparative advantages we shall speak of after having described them both by the aid of drawings made from the most improved machines of both kinds. See *Plate* IX. which contains a drawing of

A Water spinning frame, taken by the writer of this article from Messrs. Strutts' mill, Belper, Derbyshire, whose works are the most complete for the water-spinning trade of any in the country. *Fig.* 1. is an elevation in front of the whole frame; *fig.* 2. an elevation endways, and *fig.* 3. is a plan: the remaining figures are the parts on an enlarged scale. In all the three first figures, the same parts are designated by the same letters of reference: A is a bevilled wheel, fixed upon the horizontal axis, which extends through the whole length of the mill. This turns a smaller bevilled wheel upon a vertical axis B, which has a drum, C, at the lower end, and by a strap, *a*, actuates the whole machine. Another strap, *b*, goes the other way, and works another frame on the opposite side, the drum, C, being common to both. The spindle, B, passes through the drum, C, with a circular fitting, so that it slips freely round within it, without giving motion to the drum, except when it is cast into gear. This is done by two locking bolts, shewn by dotted lines passing through the drum, and both fixed into a collar or socket-piece *d*, fitted to slide up and down the spindle. It has a groove formed round it, in which a fork, at the end of a lever *e*, is received, so that the fork embraces the piece, *d*, in the groove, and when lifted up, raises the two locking bolts with it. This lever is raised by the power of a second lever D E, the extremity, E, of which, being depressed, raises up the lever *e*, and unlocks the drum from the spindle B, by withdrawing the locking bolts from their contact with an arm, *f*, of a wheel, *g*, which is fixed fast on the spindle beneath the drum, and therefore turns with it; but the locking bolts being let down, that their ends may project through the drum, and intercept the cross arm, *f*, of the wheel, the drum and all the machinery are put in motion.

The endless strap, *a a*, passes, as shewn in the figure, the whole length of the frame, makes a turn round the pulley *m*, and comes back again. Other pullies, 1, 2, 3, of the same dimensions as *b*, are situated, at intervals, in a direct line between the drum *c*, and the pulley, *m*, to bear the strap, and in the intermediate spaces between these pullies, the vertical spindles marked *n* are placed in pairs, exactly opposite each other. On the lower end of these, small wheels, *x*, called binders, are fixed, and the strap, *a a*, pressing against them, as shewn by the figure, turns them round, the object of the pullies 1, 2, and 3 being to bend the strap out of the straight line sufficiently, to make it apply to the surfaces of the several binders and turn them round. The last pulley, *m*, is fitted in a frame, and can, by a screw 4, be moved to strain the strap tight. Above each binder, and on the same spindle, a wheel, *h*, is fixed: it receives two belts *i*, *k*, (*fig.* 3.) which turn four of the spindles *l*, *l*, *l*, *l*, each belt giving motion to two spindles. The binders *x*, (see *fig.* 5.) are fitted to slip round on their spindles *n*, but can, at any time, be united thereto, to give them motion by a locking bayonet 9, which is cast in or out of action, at pleasure, by a small lever 10, in exactly the same manner as the locking of the principal drum: therefore, by the lever 10, any four spindles can be detached from the machine at pleasure. The spindles, *n*, of the binders have each at the upper end a pinion, which turns a face or contrate wheel *p*, fixed upon the spindle of the front rollers which give out the cotton to the spindles. These rollers are arranged in distinct heads or frames, containing four lengths in each, which supply four spindles.

The conſtruction of one of the heads is ſhewn in *figs.* 4, 5, and 6; *fig.* 4. being a ſection of the rollers and ſpindle; *fig.* 5. a front view of the rollers; and *fig.* 6. an end view. In theſe, *p* ſtill denotes the face wheel, and 4 the lower front roller. Upon this, which is fluted in the acting parts, the upper rollers 5, made in two ſeparate lengths, reſt, and are preſſed down upon the lower one by two heavy weights, 6, 6, which are ſuſpended, by means of hooks, 7, from the necks or ſmall parts of the upper rollers, and thus keep them firmly down upon the flutes of the front roller 4. On the oppoſite end of the front roller to the wheel *p*, a pinion, *r*, of eleven teeth is fixed: this turns a wheel, *s*, of 28 teeth, which is mounted on a ſtud or pin, and has a pinion, *t*, of 16 teeth fixed to it, which works a wheel, *w*, of 32 teeth, fixed on the end of the middle roller, ſhewn in the ſection, (*fig.* 4.) at 12, whoſe motion will be to the front roller nearly as five to one. On the other end of the roller is a pinion of 10, which turns another of 15, on the back roller, 13, by means of an intermediate wheel, ſo that this turns only once for one and a half turns of the middle roller; conſequently, the roving 14, (*fig.* 4.) which is introduced between the back rollers, from the bobbins or cops ſet up in a frame F, (*figs.* 1 and 2.) above the machine, is, in paſſing between the back and middle rollers 12 and 13, drawn out one and a half times; then between the middle and back rollers 12 and 14, it is extended five times more, making a draught or extenſion of $7\frac{1}{2}$ times in the whole; and as faſt as the rovings come through the front rollers, they are twiſted into a thread by the rapid circular motion of the ſpindles. But theſe we have to explain; they are ſtraight ſteel arbors, *l*, *l*, (*fig.* 4.) on the lower end of which the whirls or pullies, which receives the band, *i*, for them, are fixed: theſe ſpindles are mounted in a frame common to them all, which conſiſts of two rails 14, 14; the lower one ſupporting the points or toes of the ſpindles, and the other having bearings for the cylindrical parts of each ſpindle, and a ſtrip of wood is ſcrewed againſt this to keep them up to their bearings. Above this bearing the ſpindle is only a ſtraight cylindrical wire, and on the upper end of it the flyer, 15, is faſtened, either by ſcrewing it on, or it is ſtuck faſt on by friction, which is ſufficient to carry it about. The two arms or branches of the flyer are ſufficiently diſtant for them to revolve round clear about the bobbin 16, which is fitted looſely upon the cylindrical ſpindle, and with liberty to ſlide freely up and down upon it. The weight of the bobbin is ſupported by reſting on a piece of wood 17, attached by ſcrewing to a rail M, which has a ſlow riſing and falling motion, equal in extent to the length of the bobbin between its ſhoulders, by which means the thread, as it comes through the eye formed at the ends of either of the branches 15, of the flyer, and is wound by the motion thereof upon the bobbin, becomes equally diſtributed throughout, its length giving it a cylindrical figure, inſtead of heaping all the thread at one part, like a barrel, as would happen if the bobbin did not riſe and fall. This motion of the bobbin is produced by a bent lever, 16, (*figs.* 1. and 2.) ſuſpending the rail M, with all the bobbins upon it, from the arm 16; the lower end of the other arm, 17, bears againſt, and is moved by a heart or eccentric wheel 18, nearly of the figure of a heart, which is fixed on an horizontal axis extending the whole length of the machine, and at the other end it bears a ſimilar heart 18, (*fig* 1) fixed on it, which operating upon another lever 16, ſuſpending the other end of the rail M, thus cauſing it, when the hearts are turned round, to riſe and fall equally at each end, or parallel, and move all the bobbins reſting upon it together. The motion is given to the ſpindle of the heart 18, by a ſmall contrate wheel on the end of it, which is turned by a pinion on the lower end of the vertical ſpindle 19, receiving its motion by a pair of bevilled wheels from an horizontal ſpindle 20, in the middle of which is a cog-wheel 21, turned by a ſpiral piece of iron 22, which is fixed on the main ſpindle B, juſt beneath the great bevilled wheel. It operates in the ſame manner as an endleſs ſcrew, turning the wheel, 21, round one tooth for every revolution of the main ſpindle, and this ſlow motion is communicated by the ſpindle 19, and wheel-work juſt deſcribed, to the hearts, which revolve with ſuch a velocity, as will cauſe the bobbins to aſcend and deſcend ſo faſt, that they lie every turn of the thread cloſe by the ſide of that preceding it, but not upon it, ſo that the figure of the bobbin, when filled with thread, will be nearly cylindrical.

The bobbins of the roving frame are put upon a wire, or temporary ſpindle, and in this ſtate are ſet up in the frame, F, in two rows, one above another, ſo that they will all turn freely round when the rovings are drawn off from them. Theſe rovings are conducted over wires, as ſhewn in *fig.* 2, to lead them in the right direction, and are brought, two together, through wire ſtaples fixed in the board G (*fig.* 4.), then through notches made in the edge of a piece of iron plate fixed on the edge of the board, and projecting up above the ſurface of it, and after paſſing through theſe notches the rovings enter the back roller 13, in *fig.* 4. The board, G, has a ſhort traverſing motion backwards and forwards, by which means it cauſes the roving to travel backwards and forwards between the rollers, or it would ſoon, if conſtantly conducted through the ſame part of the rollers, wear out the flutes at that part, making a ſmooth ring round it: but by this traverſing motion the wear is equally diſtributed over the whole length of the fluted rollers, and does not act partially at any one part. The motion is cauſed, as ſhewn in *fig.* 4, where 18 is the ſpindle of the hearts 18 (*fig.* 2.), ſituated immediately beneath the board G: it has a cog-wheel of 18 teeth fixed upon it, turning another, H, of 36 teeth, on the axis of which a ſmall crank, K, is formed, and by means of a connecting rod draws the board, G, backwards and forwards every time it makes a revolution, by means of the cog-wheels, which will be once for every two turns of the hearts. The rovings, two together, as before ſtated, enter between the back rollers, and then paſs forwards to the middle pair, receiving in the paſſage a draught or extenſion of one and a half; then advancing through the middle rollers to the front, they are, by the motion thereof, drawn out five times, and in this ſtate delivered to the ſpindle L, which twiſts the fibres round each other the inſtant their ends come out, before the rollers leave the other ends, or they would fall to pieces, being drawn out ſo fine, that the coheſion of the fibres is inſufficient to bear any thing, and the twine given to the roving is entirely loſt, for it was at firſt only one turn in $1\frac{1}{2}$ inch in length; and this $1\frac{1}{2}$ inch, being by the draught of the roller drawn out to more than 13 inches, the twiſt of one turn in this length is imperceptible, and adds no ſtrength whatever to the roving, ſo that it is neceſſary the ſpindle ſhould, by the connection of the thread 41, paſſing down from the rollers to its flyer, give a twiſt to the fibres the inſtant they come through the roller, ſo that by twiſting one end of each fibre round the other, whilſt the oppoſite ends are held faſt between the rollers, they will become a thread ſufficiently coheſive to advance towards the ſpindle, and receive its full quantum of twiſt to become a hard and ſtrong thread: it paſſes through a wire eye or ſtaple fixed in a board at 34, which changes its

direction into a line with the ſpindle, to which it is connected by paſſing through the eye formed at the end of either of the branches of the flyer, which revolves with the greateſt rapidity along with the ſpindle, and thus give twiſt to the thread. The bobbin does not partake of the motion of the ſpindle, but is retained by the friction of its lower end reſting on the piece of wood 17, and this is increaſed by a waſher of leather put under it: then, as before explained of the bobbin of the roving frame, the thread, by the motion of the flyer, drags the bobbin about after it with a velocity equal to the difference between the motion of the end of the flyer, and the motion of the thread as delivered out by the front rollers. When the frame has been ſo long at work, that the bobbins become filled with thread, the child in attendance, by the handle of the lever 10 (*fig.* 5.), diſengages the binder *x*, of the four ſpindles from its axis *n*, and then they, as well as the head of the rollers belonging to them, ſtop, and the child breaks the thread; then pulling off or unſcrewing the flyer, he lifts off the bobbin, puts on an empty one, on which the end of the thread is previouſly lapped to make a beginning: the flyer is next fixed on, the thread paſſed through the eye at the end of the flyer, and it is ready to work again: the eye of the flyer is made open at one part, being curled in the manner of a cork-ſcrew juſt at the end, ſo that the thread can be hooked in and out of it by the child, but is in no danger of getting out by the motion of the flyer in its work. When a thread accidentally breaks, it is not always neceſſary to ſtop the ſpindle to unite it, but the attendant takes hold of the broken end which belongs to the bobbin, and draws off a conſiderable length, a yard for inſtance, from the bobbin, and breaking it, throws this away, becauſe it has every chance of being unſound: then taking the end in the finger and thumb, and applying it againſt the end of the roving which is coming through between the rollers, leaving them overlapping a ſmall quantity, and letting them go from the finger and thumb, the ends are inſtantly twined together, and united into one ſound thread. But this requires ſome dexterity, for if the end of the thread is held ſo long between the fingers in applying them together, that the roving coming through the rollers advances the length of the fibres of the cotton before it is let go, and ſuffers the ſpindle to twiſt it, the fibres will part and the thread breaks aſunder, or is never formed at that part; it is therefore neceſſary to catch the roving as cloſe as poſſible to the rollers, and apply the end of the thread quickly to it, then letting them go inſtantly, the fibres are twiſted in with each other, and the union takes place ſo perfectly, that it cannot be afterwards diſcovered where the joint was made. The lower rollers are made of caſt iron, turned extremely true, and fluted by an engine; the upper rollers are alſo caſt iron, but are covered with leather in the acting parts, ſo that this ſoft ſubſtance holds the cotton more firmly upon the flutes of the lower one than any other method would, as the roving is not liable to lap round the rollers like the ſliver of the drawing frame. No clearer is uſed; but inſtead thereof, a ſmall wooden roller covered with leather is placed over, between the front and middle roller, but it merely lays upon them, having no pivots or ſupport; its ſurface is rubbed over with chalk or whiting, and this it communicates to the leather of the upper roller, and is found to improve their action, probably by not ſuffering the cotton to ſlip beneath the rollers: *fig.* 4. ſhews, that the middle and back rollers have their weights to keep down the upper rollers upon them in the ſame manner as the front rollers; but the weights are very different, the front weight, 6, being 20lbs., whilſt the middle weights are but a few ounces, and the back rolls have a weight of 2lbs. The reaſon for the front roller requiring ſo great a weight is, that it is neceſſary for them to preſs and hold every one of the fibres of the roving while paſſing through them extremely tight; becauſe if it only held a few in the middle of the roving, the others towards the edges of the roving might, by the twiſting, be drawn out before their ends were fairly twiſted into the thread, and this would render the thread fuzzy in its whole length: the inſtant the foremoſt end of a fibre comes through between the rollers, it ſhould, by the twine of the ſpindle, be twiſted over the middle of ſome other fibres which are coming through, and over the ends of others which have altogether eſcaped the roller, and the ſmoothneſs of the ſurface of the thread altogether depends upon this being done inſtantaneouſly on the foremoſt end preſenting itſelf through the rollers; for the effect of all the preceding operations has been to diſperſe the ends of the fibres equally, ſo that they effectually break joints with each other, and then being equally twiſted, it forms a thread of equal ſtrength in all parts.

The numbers of the wheel-work for the rollers of the roving frame, are varied with every different number of cottons which is to be ſpun; the draught being altered, when requiſite, to produce ſuch an extenſion of the ſliver in paſſing through the rollers, as will make the roving, when finiſhed, 4.3 times the weight (length for length) of the yarn it is to be ſpun into. This is a pretty general rule in cotton-mills, and the roving is occaſionally meaſured and weighed, to aſcertain if the machines are drawing the proper quantity, and if not, the pinions are changed for others which will produce the proper degree of extenſion. It is in this ſtage that the ſize of the yarn is determined, and the ſpinning frames have, in general, the ſame draught; but the velocity of the ſpindles with reſpect to the roller, ſo that they will give a greater or leſs degree of twine to any given length, is varied in ſpinning different kinds of twiſt, whether hard or ſoft twiſt. The alteration is made by employing larger or ſmaller pullies, or whirls, on the ſpindles which cauſe them to revolve with a ſlower or quicker motion. Neither do the rollers of the ſpinning-frame give out the ſame quantity of roving in a given time when ſpinning coarſe or fine goods, or when ſpinning very high numbers, as No. 60: the front rollers are adapted by the wheel-work to revolve at the rate of 35 times *per* minute; but for coarſer goods, ſome of them will turn 60 times *per* minute: this is becauſe a fine thread requires more twiſt in a certain length than coarſe.

The frame from which the drawing was taken contained ten heads, or forty ſpindles, on each ſide, the frame = 80, and the ſame on the oppoſite ſide of the drum, to be driven by the ſtrap *b*, making 160 ſpindles, actuated by one cog-wheel A.

The conſtruction of the locking bayonet *d*, for connecting the drum with the main ſpindle, we have explained; but one circumſtance was then unnoticed, *viz.* that the bar *f*, *fig.* 1, is not permanently fixed to the wheel *g*, but that the wheel has a groove turned in the edge of it like a pulley; and an iron hoop or clip, made in two halves, ſcrewed together, is fitted round the wheel in this groove, and to this clip the croſs-bar, *f*, is united, by the ends of it turning down, and being received between the ends of the clip, the ſame ſcrew-bolts holding all together. The conſequence of this conſtruction is, that the machine is not ſuddenly jerked into motion when the bayonet is let down, and intercepts the arm *f*, which is revolving rapidly with the ſpindle and wheel *g*: inſtead of jerking the frame, the bar, *f*, for a moment becomes ſtationary againſt the point of the

bayonet, the wheel, *g*, flipping round within the clip, but the great friction of this foon fets the machine quietly in motion; and when it arrives at its full fpeed, the friction of the clip is fufficient to keep it in motion, without flipping any more, unlefs an accident happens, and then it is very ufeful, as it prevents the machine being broken.

The *throftle fpinning-frame* is delineated in *Plate* X. of which *fig.* 1. is a fection taken acrofs the length of the frame; *fig.* 2. is an end view, and *fig.* 3. is an elevation of the machine in front. After the minute defcription we have given of the conftruction and operation of the roving-frame and water-frame, it will not be neceffary to be very diffufe in our account of this machine, which has the fame parts as thofe machines, but only differs in dimenfions and proportion. The fame letters of reference are employed in all the figures, and A A reprefents the live and dead pulley actuating the whole, fixed on the end of the fpindle of a long tin cylinder B, which is called the throftle, and turns all the fpindles and other machinery at once. On the main fpindle of the throftle a pinion, *a*, is fixed: this turns a wheel *c*, which has a pinion, *b*, fixed on it, turning the wheels D and E (*fig.* 2.) by the intermediate wheels, *d*, on one fide, and *e* and *f* on the other. The wheels, D and E, are fixed on the ends of the fpindles of the front rollers X, as is plainly fhewn in *fig.* 3. Thefe rollers are made in lengths, which ferve fix fpindles, and the lengths are united by connecting boxes, as fhewn at F, to other lengths, fo that one train of wheel-work, *a* C *b d e f* E and D, will turn the front rollers for 112 fpindles, or 66 on each fide of the frame, and then the rollers are made in 11 lengths. Some frames are longer, others fhorter than this. Our drawing only contains 12 fpindles, and two of thefe at each end are removed, to fhew the works infide of the frame: at *g* a pinion is fixed on the fpindle of the front roller, and turns a wheel on the end of the middle roller, by an intermediate wheel and pinion on a ftud; and at the oppofite end of the middle roller is a wheel *h*, turning the back roller with its proper velocity by means of an intermediate wheel, fo that the motion of the rollers in this frame is exactly the fame as in the water-frame. The fpindles, *l*, *l*, are all driven by bands from the throftle cylinder B, the manner in which they crofs being fhewn at *k*, *fig.* 1. The bands are very loofe, and, as the figure fhews, are inclined, fo that their weight tends to draw them tight, and turn the fpindles, *l*, *l*, about with the proper velocity; but ftill the child attending the machine can, by preffing his knee againft the whirl, as the pulley is called, ftop the motion of any one fpindle for a moment whilft a broken thread is repaired, the band flipping round it all the time. The fpindles, being exactly the fame as the water-frame, need little explanation, more than to enumerate their parts, which are, the bobbin *m*, the flyer *n*, ftuck by friction, or elfe fcrewed on the top of the fpindle, and its branches ending in a curled hook, through which the thread is paffed to the bobbin. This is fitted quite loofe on the fpindle, and refts its weight on a piece of wood *o*, fixed to the underfide of a rail N, which rifes and falls, to lay the thread regularly in a coil upon the bobbin, as faft as it is taken up thereby. The rife and fall are thus produced: the two rails, N, N, on oppofite fides of the frame, are fufpended by iron rods, *p*, *p*, from horizontal levers G, which are mounted on an axis, extending the whole length of the frame, and having as many of the levers, G, upon it, as are neceffary to fufpend the rail, N, without bending. H is an iron rod jointed to the lever G, and coming down to a fhort lever I, which, at the oppofite end to its connection with H, refts on the furface of the heart R, fixed on a fpindle, which is turned by the following train of wheel-work. The fpindle of the wheel and pinion, C *b*, paffes through the frame, and by a pair of bevilled wheels, L (*fig.* 3.), turns a vertical axis M, on the lower end of which is an endlefs fcrew, giving a flow rotation to the fpindle of the hearts by a tooth-wheel, *m*, thereon, which is turned round one tooth by every revolution of the endlefs fcrew. A heavy weight, P (*fig.* 1.), is fufpended from the lever, G, to counterbalance, and caufe the end of the lever, I, always to prefs upon the furface of the heart R, which, as it turns round, elevates and depreffes the bobbins on the oppofite fides of the frame alternately. The joints of the levers, G and I, with the rods, H and *p p*, are made, as the figure fhews, adjuftable; that is, the centre pins are fixed to the levers by fitting in grooves, and are held in by nuts, fo that they can be fixed at different diftances from the centre, to accommodate the acting radius of the levers, fo that the motion given by the heart, R, may be made to correfpond with the length of the bobbin between the fhoulders.

The bobbins for the roving are fet up in a frame at S S T, between the two fets of rollers, X, X, and the roving is conducted immediately between the back rollers: but, as it goes through the fame procefs as before defcribed in the water-frame, it is needlefs to repeat it. The traverfe motion, to prevent the cotton wearing away the rollers in any one part, is fometimes omitted; but we have feen throftle frames in which the whole of the frame S T, confifting of one board, S, below, and another, T, above, connected by proper pillars, together with all the bobbins of rovings, had a fmall traverfe motion, which is found to be a great advantage in the wear of the rollers.

Refpecting the comparative advantages of the throftle-frame and the water-frame, cotton-fpinners are divided in their opinions: the fimplicity, and confequently low price in the firft erection of the throftle, is its recommendation, and it is generally ftated to be driven with far lefs power, becaufe it has fewer parts. To fet againft thefe advantages, it is faid, that when the bobbins are filled, and require to be changed, the whole frame of 112 fpindles muft be ftopped at once, by fhifting the ftrap to the dead pulley A; whereas in the water-frame, any four fpindles can be ftopped together, by cafting off their binder; and it is only neceffary to ftop the whole frame by the cafting off the great drum, when the frame is to be repaired, or is out of ufe for a day, or longer period.

We have now explained the manner of fpinning cotton into a thread by the water-frame, and fhall proceed to defcribe the conftruction of the other method of fpinning, *viz.*

The Mule.—This machine was introduced by a Mr. Crumpton, who lately received a reward of 5000*l.* from parliament for the invention, which, as before mentioned, confifted only in the combination of Hargreave's fpinning jenny with fir Richard Arkwright's drawing rollers. *Plate* XI. contains drawings of one of the beft conftructions of this machine, in which *fig.* 2. is an end view of the whole machine, and *fig.* 1. an end view of the carriage alone. *Fig.* 3. is a front view, and *fig.* 4. is a view of the operative parts detached: *fig.* 5. a fimilar view in another ftage of its operation. As this machine is extremely complicated in its movements, it will firft be proper to explain thefe movements before entering upon the machinery which caufes them. This is fhewn in *figs.* 4 and 5, where W reprefents a bobbin of the roving frame fet up in a proper frame, and the roving is conducted from it, through three pairs of rollers, A, B, and C, which have the fame draught as the

rollers for the ſpinning-frame, and are moved by ſimilar wheel-work: but the upper rollers, *a*, *b*, *c*, are weighed down in a different manner: thus, *d* is a piece of metal reſting on the neck of the front roller, *a*, at one end, and the other end upon the middle of a ſecond piece *e*, which bears upon the necks of the other two pairs of rollers, *b* and *c*; then an iron rod *f*, coming down from the piece *d*, loads all the three upper rollers *a*, *b*, *c*, at once, by means of a lever *g*, which is hooked beneath a fixed rail of the framing ſupporting the rollers at one end, and the other is made with a heavy knob, ſo that the purchaſe, or leverage of this piece *g*, draws down the wire, *f*, with ſufficient force to load all three rollers with their relative forces: thus it is plain the roller, *a*, muſt bear the principal weight of the lever *g*, becauſe the wire, *f*, is nearer to the roller *a*; but as it acts upon the piece, *e*, with a conſiderable length of leverage it bears lightly upon it, and this again bears upon two, and therefore ſtill leſs upon either, the weight of the end of *d* being divided upon two rollers *b*, *c*; but it bears moſt powerfully upon *c*, the point or end of *d* being neareſt to that roller, ſo that the operation of all theſe pieces is to load the three rollers nearly in the ſame proportion as the rollers of the ſpinning frame: but this proportion can readily be altered by ſhifting the acting lengths of the levers.

The roving, after paſſing through the rollers, is taken up by the ſpindle D G: this is placed rather inclined, but without any bobbin or flyer, like the ſpindle of the water frame; it is merely a plain conical arbor, ſupported at its point, or toe, in a ſtep made on the rail, E, of the frame, and in a bearing at F, againſt another rail. It has nothing to keep it up againſt this bearing, the draught of the band, which paſſes round the pulley *h*, and gives motion to the ſpindle, being ſufficient for this. The end of the thread is merely lapped round the upper end of the ſpindle, and its accumulation upon itſelf ſoon forms a maſs G, which is called a cop, or coppin. Now it is evident that, from the inclined poſition of the ſpindle, it will, when turned round, give twiſt to that part of the thread which is between the end of the ſpindle and the roller A, although the ſpindle and the direction of the thread do not coincide, becauſe, when the ſpindle is turned, the thread will ſlip over the top end of it and receive a twiſt, without winding up upon the cop; but when it is required to wind up, the thread, or wire H, is preſſed down upon the thread. This removes it from the end of the ſpindle to the middle of the cop, as ſhewn in *fig.* 5, and then the motion winds up the thread upon the cop inſtead of twiſting it. The wire, H, is extended at the end of a lever H I, moveable on a centre I, in the manner ſhewn in *fig.* 5, but when left at liberty, the weight of the oppoſite end of the lever reſtores it to the poſition *fig.* 4, and then the ſpindle twiſts the thread inſtead of winding it up.

The operation of the machine is this: the rails E and F, ſupporting the ſpindle, are part of a carriage or frame carrying above 100 ſuch ſpindles, and moving on wheels which traverſe on railways to and from the rollers in a direct line, for the extent of a yard and a half. Now ſuppoſe it wheeled home, that the ends of the ſpindle are cloſe to the front roller A, then ſuppoſe the rollers ſet in motion, they take in the roving from the bobbin W, and draw it out or extend it eight or more times, giving it out between the front roller A, to the ſpindle G, which, with its carriage, recedes, by the movement of the machine, from the rollers, taking up the thread as faſt as it comes out between them; and, at the ſame time the machinery draws the ſpindle back, it turns it round rapidly, giving twiſt to the thread as faſt as the rollers deliver it out, and thus producing ſuch a compreſſion of the fibres by twiſting them round each other, as will form a thread of ſufficient ſtrength to bear *ſtretching*. This means, that when a yard of thread has been given out by the rollers their motion ceaſes, ſo that they deliver no more, but the ſpindle continues to recede from the rollers to the further diſtance of a yard and half, twiſting the thread all the time it ſtretches it out in length, till it forms a fair and ſtrong thread. The twiſting motion of the ſpindle then ſtops, as does alſo the drawing-out movement of the ſpindle, with its carriage. Thus one yard and a half of thread is made and finiſhed. The attendant to the machine now thruſts the ſpindle, with its carriage, home to the rollers, holding the wire H, done in the manner ſhewn in *fig.* 5, and at the ſame time turning round the ſpindle at ſuch a rate, that it will wind up the thread upon the coppin, and the wire H, which is held down by the hand, is ſo humoured, as to make the thread wind up with regularity. The rotatory motion given to the ſpindle is, in this inſtance, done by the other hand of the attendant, and is ſo accommodated, as to wind up the thread juſt as faſt as the advance of the ſpindle towards the rollers requires, and no more; but when it arrives cloſe to them, the wire, H, is raiſed up, and the machinery is put in motion again, the rollers begin to draw out, and the ſpindles to recede, turning all the time. The mechaniſm by which all this is effected is deſcribed by *figs.* 1 2. and 3; firſt, ſee *fig.* 2, where K is a live and dead pulley for the endleſs ſtrap actuating the whole by the power of the mill. The pulley is mounted on a ſhort ſpindle, having a winch or handle, L, at one end, and on the other a large pulley M, which has a number of different-ſized grooves formed round it, to receive an endleſs rope *i*; ſee alſo *fig.* 2: this rope, after making a half turn round M, paſſes under a wheel *k*, fixed on a pin or ſtud projecting from the frame. From this wheel the rope, *i*, proceeds to another wheel, *l*, at the oppoſite end of the frame, and returning from this goes over a wheel ſituated cloſe behind *k* on the ſame centre pin. The ends of the rope are then joined, and it forms an endleſs band, which, when the ſtrap is caſt on the live pulley *k*, and the wheel, M, turned by it, the rope, *i*, conſtantly runs in a ſtraight line from the wheel *k* to *l*; but in this paſſage the rope makes a quarter turn round a wheel *m*, upon a vertical axis, which is mounted on the frame or carriage E F, for the ſpindles D, G, ſhewn ſeparately in *fig.* 1. The rope, *i*, not only paſſes round the wheel on this ſpindle, but goes forwards into the carriage, and paſſes round a groove upon the upper end of a vertical drum, (not ſeen in the figures,) which has ſeveral bands upon it, each driving two ſpindles, D, by paſſing round the pullies, *h*, of two of them, as ſhewn in *fig.* 3, in which it is alſo ſeen that the bands are all at different heights, that they may not interfere with each other upon the drum, but each take its proper place upon the length thereof. The carriage runs upon four wheels 1, 2, (*fig.* 2.) two of which are placed at each end, and run upon an iron railway, ſo that the carriage containing all the ſpindles and drums runs backwards and forwards, to and from the rollers, for the length of a yard and half. But during this motion, the power of the mill is all the time conveyed to turn the ſpindles by means of the endleſs cord *i*, which, as beforementioned, making a ſtraight line from the wheel *k* to *l*, will not be affected by the motion of the carriage, but will always circulate round the ſeveral wheels, and give motion to the drum which turns the ſpindles: 4, (*figs.* 1 and 2.) is an iron bracket, ſupporting the axis I I of the lever, H, *fig.* 4, which ſupports the wire H, and as many of theſe levers are fixed on the axis I, as ſhewn in *fig.* 3, as are ſuffi-

cient to make the wire H, ftiff enough to prefs down all the threads together, in the manner of *fig.* 5. The remaining parts of the carriage, being only its frame, are evident from *fig.* 1, and need no farther notice, except a double pulley; that is, a pulley 5, with two grooves upon it, fitted on a ftud or pin in the underfide of the frame, between the two wheels 1 and 2. The ufe of this pulley, with its ropes, as we fhall defcribe, is to make the whole carriage move parallel, or both ends equally, which, in a carriage of twenty feet long, requires fome nicety. As the two wheels 1 and 2 cannot be placed very diftant, and therefore give little fteadinefs to a carriage of fuch a great length, the parallelifm is thus preferved: a rope, 6, is made faft at one end to a fixed part of the framing, then paffes a quarter round the upper groove of the pulley 5, and runs along the whole length of the carriage, and turns a quarter round a fimilar pulley 7, *fig* 3, and then goes forward parallel to its firft direction, from 6 to 5, and is made faft to the frame in a fimilar pofition to 8, *fig.* 2, but at the farther end of the frame. In the fame manner, another rope is faftened to the frame at 8, and making a quarter turn round the lower groove of the pulley 5, proceeds the whole length of the carriage, makes a quarter turn over the pulley 7, *fig.* 3, and proceeds parallel to the firft direction, from 8 to 5, and is made faft to the frame in a fimilar pofition to 6, but at the oppofite fide of the frame. The two ropes crofs each other in the centre of the carriage, and they always pafs over oppofite fides of the pullies 5 and 7. Their effect, which is not eafily explained without a feparate figure on purpofe, is to make the carriage move equally at both ends, for it muft do this, unlefs one or other of the ropes flip upon the grooves of their refpective pullies 5 or 7, and this they will not do if ftrained tight. We have clearly ftated the paffage of the two ropes 6 and 8, and the mechanic who knows this, will readily fee the manner of its operation, though it is difficult to explain it by words only.

We muft now attend to the wheel-work for the rollers: a bevilled wheel *o*, fixed clofe behind the wheel M, on the main axis, turns another on the end of an inclined axis *p*, *fig.* 2, at the oppofite end of which is another bevilled wheel, turning *q*, fixed on the extremity of the front roller; which being connected with the middle and back rollers by the fame wheel-work as the throftle frame, and the rollers being of a fimilar conftruction, demand no further defcription, except what we have already given in *fig.* 4, of the weights for preffing down the upper rollers. When the rollers are to be caft out of gear, it is done by difengaging the wheel, *p*, from the wheel *o*; for which purpofe the bearing for the upper end of the inclined axis carrying the former, is made in the upper end of a lever *r*, which moves on a centre pin, fixed in the ftandard fupporting the bearings for the axis of the wheel M: the lower end of this lever is connected with the end of a fhort lever *s*, moveable on a vertical centre pin fixed in the frame: this lever has an arm proceeding from the centre at right angles with that feen in *fig.* 2, and is therefore hidden behind the centre, its form being fhewn at Z, which is a plan of this lever. From this fecond arm a wire proceeds to the pendulous lever P *t v*, moveable on the centre pin *t*. Now by moving the end, P, of the lever, P *t*, away from the wheel, M, it draws the wire and arm of the lever *s*, the other arm of which acting upon the lower end of the lever *r*, to throw it inwards, throws the upper end outwards, and brings the wheel, *p*, in contact with the wheel *o*, fo that the inclined axis, and the front rollers alfo, are fet in motion, as long as the end of lever, P, is kept held towards the end of the frame. This holding is performed by its arm *v*, which, as in the figure, may be hooked under and kept down by a fmall catch *w*, and from this a fine wire, 9, proceeds back to the oppofite end of the frame, and is then linked to a fhort lever, which is fitted loofely on the fame centre pin which connects the lower end of the lever, *r*, with the arm of the lever *s*. This lever is fhewn at *z*, in the feparate figure Z, but its ufe is only to fupport the end of the wire 9, and keep it up, fo that a part of the carriage of fpindles, in running back, may, by intercepting the end of it, draw the wire and the catch *w*, thus relieving the arm, *v*, of the lever P, and this, as before explained, throws the wheel, *p*, out of gear, and the motion of the rollers ceafes. On the return of the carriage towards the rollers, a piece of wood, *x*, fixed to it, runs againft the lower end of P, and moves it back fo far that the catch, *w*, engages it. This fets the rollers in motion, which they continue, until, in the retreat of the carriage, a piece of iron *y*, *fig.* 1, projecting up from it, catches the fhort lever, *z*, near *s*, fupporting the wire 9, which being thus drawn, difengages the catch *w*, and then the wheel, *p*, is caft out of the gear with *o*, as before-mentioned, and ftops the motion of the rollers. The motion for drawing out the carriage from the rollers is thus performed: a cog-wheel R, which has a pulley fixed on againft it, receives an endlefs rope, 10, paffing round a pulley, 11, at the end of the frame. One part of the endlefs rope is tied to an iron arm projecting from the carriage, fo that when the wheel, R, is turned round, by engaging its teeth with a cog-wheel fixed upon the end of the front roller, the endlefs rope, 10, traverfes, and moves or draws the carriage out with it. The wheel R, which is called the Mendoza wheel, is made to lock in or out, by fitting it on a centre pin, which is faftened into the upper end of a lever T, (fee the feparate view,) moveable on a pin fixed in the frame. The lower end of this lever is moved by a horizontal lever, feen endways near V, which reprefents its vertical centre pin or ftud. The end of this lever, which is before the ftud, or neareft the eye, is connected by a ftrong wire with the lever P, and therefore, when this lever is pufhed by the motion of the carriage, it engages the Mendoza wheel, and draws out the carriage, at the fame time that the rollers are put in motion, and give out the roving between them; but the carriage, being drawn out to the length of roving which it is to have to ftretch and fpin the Mendoza wheel, is not difengaged the moment the rollers are caft out by the wire 9 and catch *w*, in the manner we have juft defcribed, becaufe the lever, T, carrying that wheel is provided with a catch, fimilar in its properties to *w*, that is, it holds the wheel, R, in its work until the carriage has run a yard and a half, and then it feizes a wire communicating with this catch, thus difengaging the catch holding up the lever T: the Mendoza wheel then falls back, and the drawing-out movement of the fpindles ceafes. This catch and wire are not fhewn in the figures, as it would produce much confufion, but being fo exactly fimilar in this action to the catch *w*, and its wire 9, they may be eafily imagined.

We have now to defcribe the manner in which the rotation of the fpindles is caft in and out. The reader, if not confufed by the complication of this machine, may remember that we explained the connection from the wheel M, by means of the endlefs cord *i*, to the wheel *m*, and thence to the vertical drum turning the fpindles. When this motion is to be thrown in and out, it is done by fhifting the main ftrap, driving the whole machine on the live or dead pulley K, *fig.* 3. The ftrap is guided by paffing through an eye or loop at the extremity of a lever, W Y, fixed on a

vertical axis 12. On the lower end of this axis is a long lever 13, and at right angles to this a shorter lever, which being seen endways is not apparent, but it advances some distance forwards from the centre of the lever, and has a wire, 14, jointed to it, which is extended to a lever 15, against which the carriage runs when it is pushed home, and the spindles are close up to the front rollers. When this happens it draws the wire 14, which acting on the short lever of the axis, 12, turns it round, and the lever Y W with it, shifting the main strap from the dead to the live pulley K, and thus putting the whole machine in motion; at the same time that, by the operation we have before explained, the Mendoza wheel is thrown in, and also the movement of the rollers. The former of these draws back the carriage, till, as described, the catches are released, and the movement, first of the rollers, and then of the Mendoza wheel, are thrown out. At the moment before this happens, the carriage intercepts the end of the lever 13, which is formed like an inclined plane: it is therefore thrown outwards by the carriage running against it, and the end of the lever, W, being at the same time moved, it shifts the strap upon the dead pulley, and the motion of the whole machine ceases. The attendant to the machine now takes hold of the handle L, and pushes the whole carriage back again, till the spindle comes close home to the rollers; then by the carriage striking the levers 15 and P, it shifts the strap to the live pulley, and puts the spindles all in motion together, at the same time casts, in the motion of the rollers, to give out the roving; and also it casts in the Mendoza wheel, which traverses back the carriage and all the spindles to take up the roving as fast as it comes from the rollers, twisting it by the motion of the spindles all the time.

To describe the operation of this ingeniously constructed machine, will be only to recapitulate movements which we have repeated several times over; but this recapitulation will give the order in which they succeed each other. The man or woman who attends the mule stands in front of the spindles, at such a distance from the right-hand end of the frame that he can conveniently reach the handle L. In the other hand he holds the axis, I, of the wire H. Suppose, to commence, that the spindles are closer to the rollers, then the movements succeed each other as follow:

1. The lever 15, being thrust back by the carriage running against it, draws the wire 14, and by the lever, W, shifts the strap upon the live pulley, putting the wheel M, and the wheels *k*, *l*, with the endless rope *i*, the wheel *m*, and all the spindles in motion.

2. The end of the lever, P, being pressed by the carriage, engages the wheel for the motion of the rollers, and they begin to deliver out the roving at the same time.

3. The Mendoza wheel is cast into gear, and begins to cause the carriage to retreat from the rollers as fast as they give out the roving. These first, second, and third motions, all happen at the same instant.

4. The spinning of the rovings is now performed by the above motions, the spindles twisting the rovings as fast as they are given out; but the motion of the rollers is so quick, that the twist now given is slight, but having thus extended, or taken out, a yard in length from each spindle to the roller, the piece of iron *y*, *fig.* 1, on the carriage, meets the end of the lever *s*, and

5. Disengages the wheel-work for the rollers, which are therefore stopped, and deliver out no more roving; but the retreat of the carriage and the twine of the spindles continues for another half yard, stretching out the thread, and twisting it, till the piece of iron, *y*, meets the catch of the next wire, which is not drawn in the figure, and

6. Disengages the Mendoza wheel, consequently the carriage draws out no farther. The thread being sufficiently extended and twisted,

7. The carriage takes hold of the end of the lever 13, and thus shifts the strap to the dead pulley K, *fig.* 3, and the motion of the whole machine ceases.

8. The attendant, by turning round the axis, I, of the wire H, presses down all the threads together from the points of the spindles to the middle of the coppin, in the manner of *fig.* 5; then

9. Takes hold of the winch L, to regulate the winding of the thread on the coppins, when he

10. Drives the carriage home to the rollers. In this motion the spindles all revolve, and lap up the thread upon the coppins. The revolution is caused by the endless rope *i*, which may, when the machine is standing still, be considered as a stationary rope acting upon the wheel *m*. and the drum for the spindles, and as their centres traverse, turning them all round, on the same principle as a carriage wheel is turned by rolling on the stationary road. In like manner *m* is turned, by moving along while the rope, *i*, is immoveable. Now the quantity of motion, or the number of revolutions the spindles will make during this return of the carriage, is, in all cases, the same, and the quantity of thread to be wound up is always the same; but it is evident that it will require a greater number of revolutions to wind up the length (1½ yard) of thread, when winding upon the spindle, or upon the circumference of a small coppin, than when the same coppin is increased by the accumulated thread to ten or fifteen times the size of the spindle. To accommodate this, it is necessary for the spinner to have the handle, L, in his hand, because he can, by turning this one way or the other, add or diminish so much to the number of turns the spindle will make, as will just take up the thread as fast as the carriage advances towards the rollers. Thus, at first beginning, when the coppins are small, the handle, L, will require to be turned forwards a considerable quantity, to make them wind up the thread sufficiently fast: but as the size of the coppins increase, they will come to such a diameter, that the handle requires to be held quite still. The motion given to the spindles by the return of the carriage, being then just equal to wind up the thread at the proper rate, any increase of the dimensions of the coppins after this will require the handle, L, to be turned backwards, to diminish the motion of the spindles, or they would wind up too fast, and break the threads.

The spinner accommodates the motion of the handle, L, so exactly by habit, as to keep the threads always to that degree of tension as will make the coppin compact, but not injure the thread; at the same time by the other hand, which holds the spindle of the wire H, he lays the thread regularly on the length of the cop.

The carriage, having with these precautions been wheeled up close to the rollers, the several operations are repeated as before; and thus the mule continues to spin a yard and a half upon each spindle every time it is drawn out, and then wind it up on the several coppins. A good spinner will draw out 3000 times *per* day of a mule with 240 spindles; and many women will attend two machines, having them placed opposite to each other; and while one is drawing out she will thrust home the other. This makes 108,000 yards *per* day upon each mule, or both together will make more than 1200 miles to be spun in one day by one woman; who, on the old method of the hand-wheel spinning, on which the mule is an improvement, would only have managed single spindle, instead of 480; and this single spindle would not have spun half the quantity of any one in the mule; and

with respect to the regularity and accuracy of the thread no comparison can be drawn. A mule of 240 spindles has nine drums in the carriage to turn them; all the length, therefore, is nine repetitions of *fig.* 3, which only contains the spindles turned by one drum.

The motion of the mule can at any time be stopped, if a thread break, or any other accident happens, by means of a long wooden rail, Y, which is joined to the end of the lever W Y, and extends along over the whole length of the rollers, so as to give the spinner the means of stopping the mule when standing opposite to any part of its length; for it is evident, that by thrusting this rod one way or the other, the strap will be shifted either on the live or the dead pulley, stopping or putting the wheels in motion at pleasure.

The thread spun upon the mule is much softer, and has a smoother surface than the water-twist: this is owing to the manner in which the extension of the thread is made, after it has been twisted slightly, and the fibres thereby compressed together in some degree; for the effect of stretching a slightly twisted thread is, to draw all the ends of the fibres into it. All these fibres having assumed a spirally curved form in the thread, by drawing or stretching them out in the length of the thread one among another, these fibres are drawn along with a spiral movement, and all their ends are thus brought into, and concealed in the body of the thread. This operation, at the same time it makes the surface of the thread even and smooth from projecting fibres, increases the strength of the thread by bringing them all into use; and the strength obtained by this means does not require the thread to be twisted hard, but leaves it soft and pliable, which is the great recommendation of the mule-twist.

The thread thus spun, either by the water-frame or mule, has many other operations to go through to prepare it for the market, where it is to be sold to the weaver or manufacturer. The chief end of these operations is, measuring it out in lengths, weighing it to ascertain the number, and packing it up for carriage. The first machine the thread is taken to after spinning is

The Reel; see *figs.* 1 and 2 of *Plate* XII. The former being an elevation of the end, and the other an elevation in front, a very short explanation of this machine will suffice; its framing and some other parts being evident. A A is a row of the bobbins of the spinning frame, or for mule-twist, the coppins of the mule stuck upon pins, on which they will revolve freely and give off their thread. B, *fig.* 1, is another row placed behind the former, and arranged in the intermediate spaces between the bobbins of the first row, which arrangement is necessary, because the bobbins would touch each other if all placed side by side. The threads for these bobbins are conducted between several pins or wires, stuck up in a rail of wood D, and each thread is twisted once round one of these pins, that it may be drawn off with such a degree of force, from the friction thus occasioned, as will cause the thread to lap or wind with a sufficient tension upon the reel E E, which consists of a horizontal shaft E, from which three sets of arms, F, proceed, supporting six rails, G, G, parallel to the axis, and upon these the thread is wound, as shewn in the figures at *r*. The dimensions of the reel is such, that it takes exactly a yard and a half of thread to make one turn round it: this, therefore, is the measure of length, and the mechanism which remains to be described is for the purpose of counting the number of revolutions it has made. The reel is turned round by means of a cog-wheel, H, on the end of the spindle: this is turned round by a wheel K, on the axis of which is a pulley M, to receive an endless rope, which is turned round by the mill; but the bearing for the pivot of the axis, E, is fitted in a groove, formed on the top rail of the frame, so that the wheel, H, may, by sliding the bearing in this groove, be disengaged from the teeth of the wheel K, and then the movement being thrown out of gear, the reel stops. On the opposite end of the axis of the reel, a pinion, *a*, of 14 teeth is fixed, which turns a bevilled wheel of 28 teeth on the upper end of a vertical axis *b*, which has an endless screw upon it, turning a wheel, *d*, *fig.* 1, of 40 teeth, on the axis of which is a pinion of eight leaves, turning a wheel, *e*, of 56 teeth. This wheel has a small circular ring fixed on the face of it, which is formed like a snail on the front edge, that is, its surface is not parallel to the plane of the wheel, but is inclined to it in such an angle, that in turning round it operates upon a lever, *f*, to move it backwards and forwards, and this motion is, by means of a vertical lever, *h h*, communicated to the rails, A B and D, at the top of the reel, which carry the bobbins, and also the pins, D, that guide the thread, and having thus a short traverse motion parallel to the axis of the reel, the threads are laid regularly by the side of each other, without overlaying each other in one place, as they would do without this motion, and by thus enlarging the diameter of the reel, the thread that winds upon the measure would be incorrect.

By calculating the numbers of the train of wheel-work, *a*, *b*, *d*, &c. which we have before explained, *viz.* by multiplying the number of all the pinions together, and the number of all the wheels together, and dividing one sum by the other, thus, $14 \times 1 \times 8 = 112$, the product of all the pinions: again, $28 \times 40 \times 56 = 62,720$, the product of the wheels. Divide 62,720 by 112, and the result is 560; therefore the wheel *e*, of 56 teeth, will make one turn for 560 turns, or bouts of the reel. The wheel *d* makes only one-seventh of this number, or once for 80 bouts; and a pin being fixed in the back of its rim, seizes the tail of a bell, *m*, once for every turn it makes, consequently this bell rings at every 80 bouts of a yard and a half each, = 120 yards of thread wound upon the reel. The reeler, in beginning, makes the end of each thread fast to one of the rails, G, of the reel, then casts it on, and sets it going until the bell, *m*, rings; it will then have made 80 bouts, or reeled 120 yards, which is called a ley. The reel is stopped the instant the bell rings, and every one of the leys of thread, *r*, *r*, *fig.* 2, is tied up by a piece of thread to keep these 80 bouts distinct; then the reel is set on again and another ley reeled, which is tied in its turn; and when seven leys have been thus done, it makes 560 bouts, or 840 yards, which length is called a hank: the seven leys composing it are tied all together, the ends of the thread cut off, and the hanks are removed from the reel. They are got off by what is called striking the reel, to do which, the arms supporting one of the rails, G, are divided across in the middle of each, and united by hinges. When the arms are set straight, and kept so by a small bolt, the reel is of the true dimensions; but by withdrawing the bolt, and bending the arms on the hinges, the rail falls in towards the centre, and the reel is so diminished in size, that the hanks hang slack upon it, and can easily be slipped off at the end of the reel, which is lifted off its bearings for that purpose.

A reel usually winds 50 bobbins at once, and the principal care of the attendant is to watch the bobbins, supplying others, and tying the ends of the threads as fast as they are exhausted.

The hanks are now twisted up into a knot, by catching one end of them over an iron hook fixed to the wall, then put-

ting a ſmall iron rod in the other end, the hank is twiſted up very hard, uſing the rod as a lever to turn it round. To prevent its untwiſting again, it is taken by the middle of its length, and without ſuffering the ends to entwine it is doubled, then the ends are releaſed, and the two halves twiſt over each other, forming a bundle or knot of thread, reſembling a piece of thick rope, about eight or nine inches in length, and perhaps two inches girt. The hanks, being thus all knotted, are weighed, to aſcertain their number. The weighing inſtrument conſiſts of a ſhort pendulum, from which an arm proceeds on each ſide, at top paſſing through the centre of ſuſpenſion, ſo that it reſembles the letter T. From one of the horizontal arms a hook is ſuſpended, by which the hank is hung on; and at the end of the other arm is an index pointing to an arch which is divided, and has figures upon it, ſhewing how many of ſuch hanks (as the index is brought to by hanging any one upon the hook) will weigh a pound. The diviſions are made by experiment, and frequently verified by means of ſmall leaden weights, which the overſeer is provided with.

As faſt as the number of the ſeveral hanks is determined by this index, they are thrown into different bins or ſhelves, and when they are to be made up for market, as many hanks of any number as will weigh ten pounds are counted out, weighed, as a check upon the weighing inſtrument, and packed up in paper, forming a ſmall ſquare bundle, which is made compact and tight in the bundling-preſs. This is a ſmall ſquare cheſt, of about eight and a half inches by nine and a half, formed of vertical iron bars ſet upon a table, and a lid of iron bars ſhuts down over the top, with bolts or other faſtenings. The bottom of the cheſt is moveable up and down by means of a rack and pinion, a ſcrew or other means, which will enable the workman to give a great preſſure upwards. The hanks are packed cloſely into this cheſt with paper round them, and the whole number being packed in, the lid is ſhut down and bolted upon them; then by turning a handle the bottom of the preſs is raiſed up, and compreſſes the bundle together into as ſmall a compaſs as is required. The bundle in this ſtate is tied round with ſeveral ſtrings, the interſtices between the iron bars compoſing the preſs leaving ſufficient room for the admiſſion of ſuch ſtrings, and for the knots to be tied to confine the bundle. In theſe bundles the greateſt portion of the twiſt is ſent to market; but what is called hard twiſt, muſt be twiſted two threads together, as is alſo ſtocking-yarn. Such thread as is intended to be doubled for theſe purpoſes, is taken from the ſpinning-frame to the

Doubling machine, inſtead of the reel. Here the threads, two together, are wound upon bobbins, as preparatory to twiſting them round each other. See *Plate* XIII., *figs.* 1 and 2, which repreſent a doubling mill; in front *fig.* 1, and endways at *fig.* 2. A is the pulley which is turned round by the mill: this pulley is looſe on its ſpindle, but has a clutch or locking-box at the back which connects it with its ſpindle, when the upper end of the lever, B, is moved towards the machine. But when it is moved the other way the machine ſtands ſtill, though the pulley continues all the time to turn round. A wedge, *a*, being put on either ſide of the lever in its mortiſe through the piece of wood D, retains the pulley, A, either unlocked or locked in gear, with the ſpindle which is fixed in the end of a throſtle-cylinder, R, and by bands turns all the ſpindles, *b*, *b*, together. The bobbins of the ſpinning-frame are ſtuck upon pins in the top rail, E, of the frame, and the threads deſcend to wires, *d*, round which they make a turn, two threads in company, to produce a friction, as before explained, ſufficient to lay the turns on the bobbin of the ſpindles, *b*, *b*, tight and even. The threads then go through wire ſtaples or eyes fixed in a rail, F, ſituated oppoſite to the bobbins *e*, *e*, which are ſtuck faſt on the upper ends of the ſpindles *b*, *b*, and being turned thereby, wind up the thread from the bobbins at E: the rail, F, is adapted to riſe and fall parallel to itſelf, being attached by radial bars to an axis moving on centre pins fixed in the frame. Its motion is occaſioned by an iron rod, *f*, which is jointed to it, and connects it to a lever, *g*, fixed on an axis; and at the extreme end of this is a lever, *h*, *fig.* 2, reſting upon the circumference of a heart, *h*, fixed on the face of a cog-wheel *i*. This is turned by a pinion fixed againſt a wheel *k*, which receives its motion from another pinion upon the end of the ſpindle of the throſtle cylinder R. By this train of wheel-work the heart is ſlowly turned round, and raiſes and falls the lever, *h*, at the ſame time giving a ſimilar motion to the rail F, and by that means regularly winding the thread upon the bobbins *e*, *e*, which are turned rapidly round by the motion of the vertical ſpindles *b*, *b*, which receive their motion from the throſtle cylinder, R, by the bands, as before deſcribed. The bobbins are ſuch as ſhewn ſeparate at X, and have a hole through them exactly fitting the conical end of the ſpindle, on which it ſticks ſo faſt, that the bobbin will, by the motion of the ſpindle, wind up the two threads together off the bobbins at E. When the bobbins are filled with double thread, they are removed to the twiſting-machine, if it is intended to make ſtocking-yarn, or if it is to be what is called hard twiſt, for ſewing, knitting, or mending-cotton, it is done in the water-frame, which, however, undergoes ſome alterations, *viz.* the ſpindles are made to turn about in a contrary direction to that in which they moved to ſpin the thread. It is done by turning the whole frame the other way about, but as this would make the rollers move the wrong way, the pinion at the upper end of the ſpindle of the binder is placed at the outſide inſtead of the inſide of the face-wheel on the end of the front roller. The rollers then turn the right way about to deliver the thread to the ſpindle, but the back and middle rollers are removed, as it is not required to draw out the thread, the rollers being merely wanted to hold the threads faſt whilſt they are twiſted one about the other, and to deliver it regularly to the ſpindle, which operates in the ſame manner as for the firſt ſpinning, except that it twiſts in the contrary direction; becauſe when any two threads are to be turned together, it muſt be done by a contrary twiſt to that which compoſed the two ſeparate threads themſelves. After ſpinning this hard twiſt it goes to the reel, and is treated in all reſpects as other twiſt is. When it is merely required to twine the two threads ſlightly together for ſtocking-yarn, the bobbins of the doubling-machine, when filled with double threads, are carried away to

The twiſting-machine, ſee *Plate* XIII., *fig.* 3. of which is an elevation endways; and *fig.* 4, another elevation taken in front. In this, A repreſents the live and dead pullies turning the whole machine: the ſtrap is conducted through an eye at the end of an iron branch *a*, affixed to a rod or beam B, which ſlides in guides beneath the machine, and can be moved endways by means of a lever *b*, which comes out in the middle of the length of the machine, and the attendant, by applying his foot to this lever, and moving it ſideways, ſhifts the beam B, and the eye at the end of the branch, *a*, guides the ſtrap upon the dead pulley: the machine then ſtands ſtill. The live and dead pulley is fitted on the end of the ſpindle of the throſtle cylinder D, which, by bands going to both ſides, turns a double row of vertical ſpindles on each ſide, E *e* and F *f*, the internal row on either ſide being placed oppoſite the ſpaces between the outer row, ſo that

the fpindles are not crowded too clofe together. On thefe fpindles the bobbins are ftuck in the fame manner as thofe of the doubling-mill; and the threads proceeding from the bobbins are conducted through wire eyes, which are fixed in rails, G, of the framing, then each twifted thread makes a turn round a wire fixed in the rails, H, juft above G, and thefe have a flight traverfe motion backwards and forwards, by which they lay the thread evenly upon the reels, I, K, which take up the threads, as before defcribed, of the reeling-machine. The reels are flowly turned round by a train of wheel-work from the main fpindle of the pulley A. This train confifts, firft, of a pair of bevilled wheels, one on the main axis, and the other at the lower end of a vertical fpindle L, which at the upper end has a pinion actuating another wheel, *g*, upon the middle of a horizontal axis, which at each end carries a pinion, turning wheels, M, N, on the ends of the pivots of the two reels. The proportions of the wheels are fuch, that the reel turns once for about 24 turns of the main throftle D, or about one for every 72 revolutions of the fpindles, and as the reel is a yard and a half about, the thread will be twifted about 72 times in that length by the rotation of the bobbin and the thread with it. The motion of the reel draws the thread off the bobbin as faft as above-mentioned, fo that the proportion of the wheel-work determines the quantity of twift which fhall be given in any certain length. The reels are provided with counting wheel-work of the fame operation as that before explained in the reeling-machine. Thus, on the end of the fpindle of the reel is a pinion turning a wheel *i*, on the axis of which is a fcrew turning a wheel *k*, and this has a pinion on it turning a wheel, *m*, by means of the intermediate wheel *l*. The fpindle of this latter wheel has a nail fixed upon it, which operates upon a lever *n*, the lower end of which preffes againft a crofs-bar, connecting the rail, H, with its fellow. On the oppofite fide of the machine there is another fimilar crofs-bar at the other end, and the two rails being thus united, form a frame which is fupported on iron radial bars *p*, *p*, which move upon centre pins fixed in the rail, G, of the frame; fo that the frame, with the rails H, H, has a free motion to traverfe without friction, and guide the threads to lay regularly upon the reels I, K. At the oppofite end of the frame a ftring is tied which paffes over a pulley, and has a weight, *r*, fufpended from it, which always draws the frame one way, and tends to keep the upper end of the lever, *n*, in contact with the fnail upon the axis of the wheel *m*. This axis has alfo a pin projecting from it, which every time the fpindle turns round, rings the bell P. The motion of the wheel-work is fo calculated, that the bell fhall ring once for every 280 bouts of the reel, and the fize thereof is fuch, that this 280 bouts fhall meafure 420 yards, being the length of the double thread hank, *r*, equal to half the length of the fingle thread hank, which is, as before mentioned, 840 yards, and the number of double thread yarn, is according to the number of thefe hanks of 420 yards each to the pound. The reels, I, K, when filled, are ftruck, and the hanks taken off them in the fame manner as the reeling-machine before defcribed.

Hard twift, which is intended for fewing, knitting, or mending-cotton, after being twifted and reeled in hanks, is fent to the bleach-field, and bleached by fome of the proceffes defcribed in our article Bleaching.

But the procefs which is moft generally in ufe for bleaching yarn, is thus conducted: an earthen-ware retort is filled with one quart of oil of vitriol, two quarts of fea-falt, and one quart of the ore of manganefe. The hood of the retort being put on and luted, it is fet over a fmall ftove or fand-bath, and the heat foon raifes from it the oxygenated muriatic acid gas, which is received in a fquare wooden cheft, about feven or eight feet fquare, and as many deep, forming a fmall air-tight chamber, in the upper part of which the goods are fufpended upon a rack or frame. The lower part of the cheft, for about three feet deep, is filled with water, fometimes impregnated with a ley of pot-afh, and fometimes with lime-water, or water mixed with lime. The gas is introduced betwixt the fluid and the goods, amongft which it afcends, and by its action upon any colour they may contain, renders them white: at the fame time, by occafionally immerfing the goods in the fluid below, it is fought to modify the action of the acid, and prevent the operation proceeding too rapidly. This is effected by means of a pole or long rod connected with the frame on which the goods are fufpended, the centre of which pole moves on a fwivel fixed in a hole in the partition, or lid of the chamber, which is occafionally ftopped with clay, and enables a perfon to raife the goods by means of a fmall crane, or, at pleafure, to let them down into the fluid, not always, however, without inconvenience, which occafioned it the name of the *Bedlam procefs*, as the workmen, if they inhale the gas, are ftupified.

Previoufly to the yarn being fubjected to the action of the gas, it is boiled in a ley of pearl-afhes, then milled for twenty minutes in a fulling mill, and the hanks are hung upon the racks or crofs rails of the fquare frame in which they are fufpended, to be let down into the bleaching-chamber. This frame is, as before-mentioned, attached to a long pole, that fufpends it from the crane, which being fwung over the chamber, is let down therein, and the lid is clofed over it, the joints being made tight with clay, and the pole coming through a hole in the lid, which is carefully made tight round it by a wet cloth. The gas is now admitted to the chamber, but the yarn is not fubjected to its action more than ten minutes before it is let down and immerfed into the liquor at the bottom of it, which thus defends it from the action of the gas for a few minutes, until it becomes thoroughly wetted, when it is drawn up again into the gas, and remains in it for half an hour to be bleached: it is then let down again, for a few minutes, into the liquor to wet it; it is then drawn up again, and in this manner the procefs continues, until fuch time as it is known, by experience, that the yarn will be fufficiently bleached. The frame is drawn up by the crane, and the cotton removed from the rails on which it hangs, and being rinfed in clean water, is carried out and fpread on the grafs in the fields, to be fubjected to the fun and air, by which the bleaching is completed. It is not the bufinefs of the prefent article to enter into the theory or chemical principles of this procefs, which will be found under the article Bleaching.

After the hanks are returned bleached, the yarn is found to be much lighter, fo that it will generally be two numbers higher: thus, cotton of N° 48 hanks to the pound being fent to bleach, will return fo much diminifhed in weight, as to require 50 of the hanks to weigh a pound. But this rule is not fo exact as is requifite; the thread muft therefore be reeled over again, weighed, and packed. A great proportion of the fewing cotton is wound into balls of a very beautiful appearance by a curious winding machine. As a preparation to this winding, the thread muft be wound off the hanks in which it was bleached to large bobbins. This is done in a machine provided with feveral fpindles, like the doubling machine, upon which bobbins are ftuck, and the thread wound on them from the hanks, when they are extended or ftretched out between two pul-

kes, or ſmall reels, on which the hank revolves in the manner of an endleſs band. Theſe bobbins are taken to the

Ball Winding Machine, ſee *figs*. 3. and 4. of *Plate* XII. the former being a plan of the acting parts, and the latter an elevation of the whole machine on a ſmaller ſcale. In *fig*. 4. A is the bobbin from the winding machine, which is ſtuck upon a pin projecting upwards from the bench, and a ſmall lead weight is laid upon the top of the bobbin, to load it, and cauſe ſuch a friction as will make the thread wind with a proper tenſion upon the ball. The principal part of the machine is a ſpindle B, which is perforated through its length, and receives the thread: it runs, in bearings, at the top of two ſtandards *a*, *b*, and at the extreme end of the ſpindle, beyond the front ſtandard, a flyer or branch, D, is fixed, and the end, *d*, of it therefore deſcribes a circle when the ſpindle, B, turns round by the endleſs band which ſurrounds the pulley E, and gives it motion from the mill. The ſpindle has an endleſs ſcrew cut upon it, turning a wheel, G, at the upper end of the vertical ſpindle F, which, at the lower end, has an univerſal joint, *e*, connecting it with an inclined ſpindle H: this, at the lower end, has a ſmall bevilled wheel, *h*, turning another, *f*, on a ſmall vertical axis, carrying, at the upper end, an univerſal joint, which communicates motion to an inclined ſpindle I, and this, by another ſimilar joint at *i*, connects with a vertical axis *r*, which has a pinion, *k*, turning a wheel *l*, upon whoſe ſpindle, *m*, the thread is lapped to form the ball, as ſhewn in *fig*. 3: the ſpindle, *m*, is ſupported by a piece of metal, K, formed like the letter L, and moveable on a centre pin *n*, which is ſituated exactly in a line with the ſhort vertical axis of the wheel *f*: M is a circular plate, on which the piece, K, reſts, when turned about on its centre pin *n*, and N is the handle by which it is turned about at pleaſure upon it. The two ſpindles, B and *m*, are, as ſhewn in *fig*. 4, on the ſame level, but are capable, as ſhewn in *fig*. 3, of being ſet at any angle to each other by inclining *m* on its centre pin *n*, and this being in the line of the ſpindle of *f*, the motion does not tend to lengthen or ſhorten the ſpindles I and *r*; but they always convey the motion, communicated from the ſpindle, B, by means of the axes F H I and *r*, to *m*, by the ſeveral wheels G, *h*, *f*, *k*, and *l*, which have been deſcribed: they are ſo apportioned, that the ſpindle, *m*, turns only once for 48, 60, or 72 revolutions of the ſpindle B. Theſe different numbers are uſed in different machines, and the appearance of the ball they will wind materially depends upon this circumſtance.

To explain its operation, ſuppoſe the ſpindle, *m*, inclined to B, as in *fig*. 3, the rapid motion of the ſpindle, and its flyer D, (over the point, *d*, of which the thread is conducted) laps the thread round the ſpindle, *m*, in an oblique direction. At firſt, the ball thus formed has no regular figure, but as the thread accumulates and forms a cone, the lapping of the thread in a regular order begins and continues, as in *fig*. 3; here it is ſeen, that the motion of the flyer will lap the thread obliquely upon the ball from one end to the other, as the figure ſhews; but at every ſucceeding revolution of the flyer, the ball itſelf has made $\frac{1}{48}$, $\frac{1}{60}$, $\frac{1}{72}$, part of a revolution upon its own axis *m*, according to the proportion of the wheel-work, and thus the thread is not always diſpoſed on the ſame oblique line, but on another parallel to it, and removed a ſmall diſtance from the former. Now it is plain, that the thread on the underſide of the ball muſt be inclined in a contrary direction to that lapped on the upper ſide; therefore, when the ball is looked at, the oblique threads of every alternate layer croſs each other, in the manner of the figure. This will, however, be much more readily underſtood from an inſpection of a ball of this kind, than from any verbal deſcription. The length of the ball depends upon the angle which the ſpindle, *m*, makes with the ſpindle B; it can, therefore, by ſhifting the handle N, be wound off of any required figure; but the moſt general method is, when about one half the ſize of the ball is wound, to give the ſpindle a greater degree of obliquity: this occaſions the ball to wind longer from that period, as well as a greater diameter: the conſequence is, that when the ball is finiſhed, on looking at the end of it a circular hollow is ſeen in it, as though it had been turned in a lathe, and ſometimes a thin membrane, conſiſting of about two or three layers of thread, is extended nearly acroſs the end, leaving the hollow beneath, which can be ſeen into from a ſmall hole in the end. This membrane is made by ſetting the handle, N, at the greateſt angle it will make, the thread then not only lays over the whole ſurface of the ball, but is ſtretched partly acroſs the end of it; and the interſection of a great number of theſe forms a tranſparent membrane, which has a circular hole in the centre. After laying this layer two or three times over, the handle, N, is returned to its original angle, and winds the ball as at firſt.

The bench or table R R, on which the machine ſtands, is made long enough to contain fourteen ſpindles, all placed in one row; and a throſtle cylinder, running along under the bench, gives motion to them all at once. Two children attend the whole fourteen, which they can readily do, having only to lap the thread, at the beginning, upon the ſpindle *m*, and then, when the ball has arrived at a certain ſize, to turn the handle N; but the period or quantity of this alteration is not of any great importance, as it only influences the figure of the ball, and, as we before deſcribed, thoſe fancy ornaments within the hollow end: theſe may, by great attention in frequently and artfully ſhifting the handle N, be made very delicate and beautiful. The machine we have juſt deſcribed was made after a model of a machine invented by Mr. Brunell, who firſt deviſed the means of connecting the ſpindles, B and *m*, by wheel-work. The machines, before this, were turned by endleſs bands, from the principal cylinder which gave motion to the whole. The defect of this method was, that the relative diameters of the wheels could not be ſo exactly proportioned, as to produce one turn of *m* for exactly forty-eight, &c. of B; that the threads of the ſucceſſive layers would lay exactly one over the other, becauſe the leaſt variation in this reſpect would greatly injure the effect of the ball. But in the machine before us, the motions are ſo accurate, that, on inſpecting the ball, it appears honey-combed, or conſiſting of regular cells, which gradually diminiſh in ſize as they approach the centre: the partitions between theſe cells are only one thread in thickneſs, but conſiſting of a great number, ſtretched ſo exactly over each other, that they form regular plane ſides to the interior of the ſeveral cells.

We have now preſented our readers with all the operations of cotton-ſpinning; but theſe operations are conducted on ſo grand a ſcale by many manufacturers, that the ſyſtem of their management, the arrangement of the buildings, the conſtruction of their water-wheels, ſteam-engines, or other firſt movers, and many other particulars, are no leſs admirable, and worthy of deſcription, than the machines themſelves. To deſcribe all theſe curioſities of the cotton trade would fill a volume; but we muſt content ourſelves with deſcribing one plate, which contains drawings of one of the moſt complete cotton-mills we have ever viſited. It is one of the four mills at Belper, in Derbyſhire, belonging to Meſſrs. Strutts, whoſe very extenſive works contain almoſt every improvement in the cotton trade. The whole of

theſe mills is built fire-proof, being without any timber beams in the floors, or much wood work of large ſize in any of the machines, which makes them very ſecure from danger by fire.

Fig. 1. of *Plate* XIV. is a longitudinal ſection of the whole mill, ſhewing all the floors, and all the machines upon them, at one view. *Fig.* 2. is a ſection, acroſs the length of the former; and *fig.* 3. is a ſimilar croſs ſection of the mill, and, at the ſame time, a longitudinal ſection of the wing, which extends from the centre of the mill, at right angles, to its length; ſo that the plan of the mill is of the figure of the letter T. We will firſt explain the manner of building fire-proof mills without timber, which has been adopted by Meſſrs. Strutts in their very extenſive works.

The ſide walls A A, B B, and the end walls C C, D D, are built up as uſual, and with the uſual doors and windows in them; the ſeveral floors, E, F, G, H, I, K, are compoſed of brick arches, as ſhewn in the figures. In *fig.* 1, theſe arches are ſhewn cut acroſs the ſpan; and in *fig.* 2, they are ſhewn cut through the crown, parallel to the axis. Theſe arches have a very ſmall riſe, and their ſpan is nine feet from one to the next. The abutments, or ſpringings of the arches, are ſupported by iron columns, *a*, *a*, as ſhewn in the figures, which are erected, one upon another, in the ſeveral floors, through the whole height of the mill. They are connected by caſt-iron beams or girders, *b*, *b*, ſhewn in *fig.* 2, one of which extends from the top of every column to the next, and forms a ſupport or ſpringing for the arches. In an oppoſite direction to theſe girders, every pair of the columns, *a*, *a*, are tied together, acroſs the arch, by a wrought iron bar, which has an eye at each end, to be hooked over the tops of the columns, and keep them tied together, reſiſting the lateral thruſt of the arch, and preventing the columns from being thruſt aſunder from each other, as they would otherwiſe be. Thus, though every floor is formed of a ſyſtem of arches, like a bridge, as ſhewn in *fig.* 1, yet the lateral ſtrain of each is ſupported by iron tyes; ſo that each arch ſtands by its own ſupports, independent of its neighbours. The arches are of only one brick thickneſs, and are covered over at top by a floor of paving bricks, to make a flat ſurface above, the haunches of the arches being filled up by rubbiſh. The iron tyes acroſs the arches are concealed within the brick-work of the arch, ſo that they do not appear; the ceilings of the rooms, therefore, conſiſt of regular arches, which have a very good appearance, and make the moſt firm and ſolid floors above that can be imagined. The roof is of caſt-iron, as ſhewn in *fig* 2, where the two columns, *d*, *d*, are a continuation of the columns, *a*, *a*, in the lower floors; and a croſs or girder beam, *e*, which connects them, is alſo a ſupport of the caſt-iron principals, *f*, *f*, of the roof; and *g*, *g*, are further ſtays, proceeding from the iron girders uniting the columns of the ceiling, *k*, beneath: the ſpace between the two columns, *d*, *d*, in the roof, forms a ſmall room, which is uſed as a ſchool-room for the work-people on Sundays. The deſks and forms are ſhewn in the figure.

The mill contains fifteen arches in length, as ſhewn in *fig.* 1. between the walls C C, D D, which are the end walls of the mills. Beſides theſe is another wall, L, to which the floors are continued by two additional arches, added beyond the end wall, C, of the mill. This ſpace forms a ſmall room on each floor, which is occupied by the counting-houſe, ſtair-caſe, and the ſtove, which warms the mill in winter, and alſo a crane of a peculiar conſtruction, for drawing up the goods to the machines on the ſeveral floors.

The ſpace of the mill, therefore, between the walls C and D, is appropriated to the machinery, as is alſo the wing, which conſiſts of ſix arches, as ſhewn in *fig.* 3, projecting from the middle of the mill, perpendicular to its length.

The width both of the mill and the wing is, as ſhewn in *fig.* 3, compoſed of three lengths of arches, having three iron girders that they riſe from, and two columns to ſupport them. The arches in the ground-floor, or cave of the mill, are ſupported by very ſtrong piers, *m*, inſtead of iron columns. Theſe piers are founded very firmly in the earth, and every caution taken to prevent them ſubſiding, or ſettling under the great weight they have to carry. The columns of the firſt floor are erected immediately upon the top of theſe piers: on the top of theſe columns are thoſe for the ſecond floor; the third ſurmount theſe, and ſo on to the top of the mill: the columns being thus erected, one upon another for the whole height of the mill, forms the ſtaunchest building that can be imagined.

We ſhall now proceed to deſcribe the machinery of the mill. The whole motion is taken from the great water-wheel M, ſituated underneath the wing, in the cave, or loweſt room of the mill; and as it is of ſo great a ſize, namely, 18 feet diameter, and 23 feet long, that no caſt-iron girder could be thrown acroſs it ſtrong enough to ſupport the arches for the wing above it, a ſtrong ſtone arch, N, is thrown acroſs from the wall *h*, which is built up at one end of the water-wheel, to the wall, A, of the mill, which is at the other end of the mill; and to reſiſt the thruſt of this arch, two ſtrong iron bolts, *x*, are extended acroſs it, and render it as ſtrong as poſſible; ſo that the iron columns of the wing over it may be raiſed upon it as ſafely as they could upon foundation piers, *m*, like the others. But as a precaution againſt overloading the walls, *b* and A, which, as they include the water-wheel, would ruin every thing, if they ſettled in the leaſt, the arches of the wing immediately over the water-wheel are built, inſtead of ſolid brick, with ſmall pots like garden pots, ſo that they are light, but ſufficiently ſtrong to bear any thing which is ever required to be loaded upon them. Theſe ſmall pots are alſo uſed to build the arched floor, K, of the roof, that it may be light, and as it has nothing to bear but the ſchool room, they are ſufficiently ſtrong to make the floor.

The great water-wheel has a cog-wheel, *o*, upon the end of its ſhaft, which turns a pinion, *p*, on a ſtrong ſhaft, that carries a wheel *q*, and thus turns a pinion on a third ſhaft, *r*: this, at the end, has a bevilled wheel, which gives motion to a vertical ſhaft, *s*, proceeding up to the top of the mill, and turning the machinery in the ſeveral floors. The bevilled wheel on the ſhaft, *r*, alſo drives a horizontal ſhaft, *t*, extending the whole length of the mill, and having upon it, juſt beneath every arch, a bevilled wheel, turning another on a vertical ſpindle, which riſes up through the two floors D and G. Theſe are the main ſpindles of the ſpinning frames, and the great frames are fixed upon them. The frames are all ſhewn endways in *fig.* 1; but in *fig.* 3, on the floor F, a pair of frames are ſhewn in front, as they ſtand ſide by ſide, and the floor, G, over it has juſt the ſame, as has alſo the wing, though not put in the drawing; but theſe laſt are turned by a bevilled wheel, *v*, *fig.* 1. on the ſhaft *s*, in the floor G, which turns a horizontal ſhaft, *v*, *fig.* 3, extending the whole length of the wing, and turning the ſpindles of the ſeveral frames as it paſſes over them. The two loweſt floors, F, G, which are appropriated to the ſpinning frames, contain 28 frames on each floor, 56 and 12 more in the two floors of the wing, in all containing 4236 ſpindles, a conſiderable proportion of which are, however, employed in ſpinning the hard twiſt. The two next floors, viz.

the 3d, H, and the 4th, I, are occupied in the body of the mill with carding machines, which ftand in three rows: they are turned by ftraps from a horizontal fhaft, extending the whole length of the mill, over the machines. In *fig.* 1. they are fhewn endways, and *fig.* 3. fhews them in front of the floor H, while that above it is juft the fame, though not drawn: in all thefe two floors are 64 breaking cards and 72 finifhers. The fame floors, H and I, in the wing, contain 16 drawing frames and four ftretching frames or mules, in which the rovings are prepared as defcribed in our account of the different methods of making rovings. The fifth floor, I, contains the reeling, doubling, and twifting machines, &c. as we have defcribed; but the numbers of the different kinds of thefe laft mentioned machines vary in every mill, according to the kind of cotton which is to be fpun in it, and that branch of trade its proprietor intended to carry on: if it is for fpinning twift for weavers, only reels will be wanted in the fifth floor; or if it is to fpin ftocking yarn, doubling and twifting machines will be wanted. Indeed thefe laft machines are altered every few years in cotton mills, according as the ftate of the trade varies from a demand of one article to another.

The fpace of the mill, between the walls C and L, contains, as before-mentioned, the ftaircafe O, which is of ftone, afcending from one floor to the next, and alfo the crane P P. This is a moft ingenious and ufeful machine, which has been adopted by Meffrs. Strutts in all their cotton mills, and it is applicable to many other manufactories. The crane confifts of a large fquare bafket, or cradle, four feet fix inches fquare in the bottom, withinfide, and fix feet deep: it is open in front. The bottom is a floor of wood, and the fides wicker or bafket work ftrongly bound with iron ftraps. This bafket or cradle is fufpended by a rope in a well P, extending from the top to the bottom of the mill, through all its floors. The cradle exactly fills the well, and is guided by iron fliders in each angle, fo that it may be fteadily drawn up from one floor to any other by the power of the mill, and ftopped or fet in motion, either up or down, at pleafure, by pulling two guide ropes, which are always in reach of a little boy who fits at the top of the cradle in a feat made for the purpofe. Now the machinery for effecting this is the only difficulty: it is neceffary, in fuch a crane, that the machinery, when caft on to draw up the cradle, fhould move with a regular and equable velocity, without making any fhock or jerk when it firft ftarts; that it fhould ftop the inftant it is required, otherwife it would be very difficult to fet the cradle, with its floor, exactly on a level with any of the floors of the mill, and if not fo, it would be very inconvenient for the people to get in or out of it.

The cradle muft alfo be let down by the power of the mill as well as drawn up, becaufe if fuffered to run down by its own weight, it would always run down too quick or too flow, and be dangerous and uncertain: it muft, at the fame time, be fo contrived, that the cradle itfelf will ftop the machine if drawn up too high, or let down too low, to prevent its being over-wound and breaking the works. All thefe conditions are effected, in the moft perfect manner, by very ingenious mechanifm, which was invented by Mr. H. Strutt, and has been adopted in all his father's mills, rendering thefe cranes as fafe and manageable as poffible. The rope fufpending the cradle in the well is double, to enfure greater ftrength, and is conducted over a pulley, or grooved wheel, fituated in the roof of the mill. The other end has fuch a weight fufpended from it, as will balance the weight of the cradle, together with half the weight of the ufual load the crane is expected to carry. This weight, therefore, draws the rope fo tight upon the grooved wheel, that it will, by turning round one way or the other, elevate or deprefs the cradle at pleafure, and at the fame time the balance weight, which has a fmall well of its own to work in. The axis of the grooved wheel has a cog-wheel on the end of it, which is turned round by a fmall pinion fixed on the extremity of an axis on which the mechanifm is placed: it confifts, firft, of a large wheel, like a coach wheel, fhewn at *x*, *fig.* 1, fixed on the middle of the axis, and on each fide of this are two broad riggers or drums to receive the endlefs ftraps, which give the motion againft thefe riggers on the outfide of each. A dead pulley or rigger is fitted loofely on the axis, and being exactly the fame fize as the live riggers or pullies, the ftrap can be fhifted from one to the other in a moment. The axis is actuated by two endlefs ftraps coming from one drawn at *y*, *fig.* 1, which is turned by wheel-work from the fhaft in the fifth floor of the mill, as the figure fhews. One of thefe ftraps is croffed between the two drums, and the other is not, fo that the motion of the two dead pullies on which thefe ftraps act are always in contrary directions to each other, whilft the axis on which they run is ftationary. The two ftraps are guided by paffing through eyes attached to a fide rail of a fquare frame, which includes the axis with both its riggers and great wheel, and is fufpended from the top of the machine by four pendulous rods, fo that it has free motion to fwing backwards and forwards in a direction parallel to the length of the axis of the pullies, which motion is communicated by a crank formed on a fpindle, having a grooved wheel on the end of it. An endlefs rope paffes over this wheel, and then defcends to the bottom of the well, where it is ftrained beneath another wheel, fo that the two fides of this rope are always in reach of the boy before-mentioned, who rides in a feat at the top of the cradle, giving him the means of turning the wheel and crank either way about, for by pulling down one of thefe guide ropes, he turns the wheel and crank, and draws the fufpended frame one way, or by pulling down the other guide rope it is drawn the other. The confequence of thefe movements is, that the endlefs ftraps are fhifted both together on one or other of their live pullies, whilft the other ftrap will be fhifted upon the oppofite dead pulley; confequently, the ftrap which is upon the live pulley turns the axis round one way or the other, drawing the cradle up or down, as it happens to be the croffed ftrap, or the oppofite one, which is fhifted on the live pulley, fixed on the axis at either fide of the great wheel, which we firft compared to a coach wheel. This is, in reality, a brake wheel, having a broad ftrap furrounding the lower half of it, both ends of which are conducted over two pullies, and levers with heavy weights draw down the ends, fo that it has a conftant tendency to prefs upwards beneath the wheel, to break, or caufe fuch a friction upon it, as will ftop its motion, when the two endlefs ftraps are fhifted upon their dead pullies; but when the fwinging frame is fhifted either way, by the boy pulling down one of the guide ropes, which go down to the bottom of the well, and either of the ftraps are thus fhifted upon the live pullies, the frame feizes the tail of a bent lever on each fide the wheel, and relieves the weights which draw the ftrap againft the wheel, and it hangs quite flack beneath the wheel, with a confiderable fpace all round, fo that its motion is quite free, and only under the influence of that ftrap which, being upon one of the live pullies, gives it motion in either direction. The crank before-mentioned for fhifting the fwinging frame is fo contrived, that it always has a tendency, by means of a weight, to affume fuch a pofition, that it will direct the fwinging frame, and the ftraps, both upon the dead pullies and the brake ftrap, being at the fame time in contact with the lower half of the wheel, the cradle will

stand still; but when the crank, by pulling one of the guide ropes which go down to the bottom of the well, is turned to shift the endless straps either way, and consequently put the cradle in motion, the crank drops into a kind of hitch, or catch, which holds it in that position, but not so fast but that it can be relieved in a moment by snatching the guide or rope, and if left to itself it then assumes that position in which the crane will stand still. By this means the crane is in no danger of any accident, as it is always under the action of one or other of the endless straps, which cause it to ascend or descend, or it is under the brake strap, which makes it stand still, and the great advantage of all these movements are, that they act so softly, without any sudden jerks or snatches in changing from one state to another. The well has a gate fixed up at every floor to prevent people falling down into the mill, and if any person, on the fifth floor for instance, wishes to descend to the third, he goes to the gate and calls the boy, who, with the cradle, is perhaps below, to come to No. 5, which he does by snatching that guide rope which makes the crane draw up, when he sees the floor of the basket come exactly opposite the floor of the mill No. 5. He snatches the opposite rope; this jerks the crank out of its hitch, and it shifts the straps and brake, stopping the cradle in an instant, so that it is seldom half an inch out of level with the floor. The person who wishes to go down can now open the gate, which he could not do before, because the latch of the gate is lifted up by the cradle, when its floor is level with the floor of the gate, and stepping into the cradle he mentions the floor he wishes to go to, and the boy pulls down that directing rope which lets him down, and stops it at the floor he wishes, by snatching the other rope; but if he should pull the wrong, no harm can ensue, because the brake will always act to stop the machine, if the straps do not act to move it. The bobbins of the spinning frame, and the cops of the mule, are set up in little frames mounted on wheels, and thus wheeled along by little children to the crane, and drawn up or let down as required, without any hard labour; in fact the stairs are seldom used except for the people to go up and down when they begin and leave off work.

The stove which warms all the mill is situated down in the cave beneath the staircase: it is very ingeniously contrived with an iron cockle, or inverted cubical vessel, beneath which a fire is made, and the smoke escapes by a flue behind into a chimney. The air is then brought in a current to strike upon the external surface of this cockle, and being thus warmed, rises up through flues into every floor of the building, where it is admitted in any quantity at pleasure by registers, which are regulated to produce an agreeable warmth, but as the warm air escapes again with a draught through a proper ventilator, there is nothing of closeness connected with it.

Our limits will not permit us to describe more of the ingenious contrivances with which Messrs. Strutts' extensive mills at Belper abound, neither could the reader form a good idea of them without additional plates, and we have already exceeded our proposed number. Messrs. Strutts very liberally permitted the writer of this article to visit their works, for the purpose of composing it, to take drawings of the principal machines, which are of the very best construction of any in the cotton trade. These would have appeared here, but that the first six plates of our series were drawn and engraved some years ago, being intended for the article Cotton, at a time when the machinery was not brought to that perfection, in point of construction, that it is now. Indeed, the mechanical ingenuity called forth in the whole manufacture of cotton, is beyond the conception of those who have not visited the countries where it is carried on. The tools and implements employed in constructing the different machines are very curious; for as there are such immense numbers of each part of every machine to be made, it becomes, in the same manner as with the clock-maker, worth the machine-maker's trouble to construct complicated tools and engines to expedite the manufacture of the parts; thus cutting engines for forming the teeth of the numerous wheels, see *Cutting* Engine. And here we would remark, that Mr. George Gilpin of Sheffield has, since the printing of that article, invented a method of cutting wheels from solid cast iron, with as much accuracy and as good a finish as brass wheels have hitherto been cut, making a very great saving in the expence of brass for a large mill, and much more durable when done. Card wires are manufactured in a very extensive scale in Yorkshire, and many very curious machines have been invented to diminish the labour of cutting and bending the wire teeth, and pricking the leathers for them: but a patent has been lately taken out, by Mr. J. C. Dyer, for a machine which cuts and bends the wires, pricks the leathers, and puts them in all at one operation, and with such rapidity, that it completes four *per* second. It is one of the most ingenious and perfect machines we ever met with, and it will prick and stick any sort or size of teeth, by altering adjustments introduced for that purpose. Drawings and a full description of this curious machine are lodged in the patent office by the patentee, who brought over the invention from America, where it has been some time in constant use. Curious lathes for turning spindles, and various other circular work, are used in the workshops of the cotton mills and fluting machines, for cutting the flutes in the lengths of the rollers of the drawing and spinning frames: in short, such works as Messrs. Strutts' at Belper, Mr. Arkwright at Crauford, in Derbyshire, Messrs. Phillips and Lees at Manchester, Mr. Peeles' and many others, are schools for mechanics in almost every department of the science; and good ones too, as the cotton manufacturers in general are convinced, that it is their interest to attend to every minutia in the construction of their machines, which may render them more durable or their operations more perfect. Among these improvements we may mention, what is becoming very general, *viz.* the addition of governors, or regulating balls, to the water-wheel, which turn the cotton mills, as they always keep it moving at the same speed, without which all the machines in the mill act irregularly, and it must happen that the velocity of the common water-wheel varies, when any number of machines are stopped, or cast in motion; but the regulated water-wheel always adapts its draught of water to the work it has to perform, preserving an uniform velocity in itself and all the machines it turns. This is brought to such perfection, that many such mills have a clock turned by the mill; close to it another clock, regulated in the usual manner by a pendulum, and the motion of the mill is so regular, that these two clocks will never vary more than two or three minutes. Both are made with dials and hands exactly alike, but one has a title on the dial, *mill* time, and the other, *clock* time. We shall take an opportunity of explaining a regulated water-wheel, under Water-wheel.

We shall here close this article, though we have only gone through the detail of cotton-spinning, because the subsequent processes of weaving cotton-thread into cloth, dressing, finishing, printing, &c., have been or will be ex-

plained under the following feveral heads; *viz.* for explanations of the weaving proceffes, fee DRAUGHT *of looms*, or CORDING, DRAW-LOOM, DRAPER, DIMITY, DORNOCK. Though the three laft are rather linen than cotton, ftill the fame proceffes apply in part to the weaving of cotton goods; fee alfo FUSTIAN, and laftly, WEAVING. For the dreffing of cloth after weaving, fee CALENDAR, or rather PRINTING *of Calico*, which precedes the calendar, except for fome particular goods; and as a part of calico-printing fee DIPPING; alfo BLEACHING, DYEING, DISCHARGING, and WASHING-WHEELS. And, as we have before mentioned, a full account of the wonderful rife and progrefs of the cotton manufacture, which is wholly founded upon the improvements in the machinery for fpinning, will be found under COTTON. Under the head of SPINNING, we fhall defcribe thofe variations of the cotton machines, which have been made to adapt them to the fpinning of flax, wool, and worfted.

MANUFACTURERS. Perfons enticing artificers into foreign countries incur the penalty of 500*l.* and twelve months imprifonment, for the firft offence, for each perfon fo feduced, and 1000*l.* and two years imprifonment, for the fecond offence. (23 Geo. II. c. 13.) And fuch artificers not returning within fix months after warning, fhall be deemed aliens, forfeit all their lands and goods, and be incapable of any legacy or gift. (5 Geo. I. c. 27.) By 22 Geo. III. c. 60. if any perfon fhall contract with, or endeavour to perfuade any artificer concerned in printing calicoes, cottons, muflins, or linens, or preparing any tools for fuch manufactory, to go out of the kingdom, he fhall forfeit 500*l.* and be imprifoned for twelve months; for a fecond offence, 1000*l.* and be imprifoned for two years.

Marbles

Marbles, *Artificial.* The ſtucco, whereof they make ſtatues, buſts, baſſo-relievoes, and other ornaments of architecture, ought to be marble pulveriſed, mixed in a certain proportion with plaſter; the whole well ſifted, worked up with water, and uſed like common plaiſter. See Stucco.

There is alſo a kind of artificial marble made of the flaky ſelenites, or a tranſparent ſtone, reſembling plaſter; which becomes very hard, receives a tolerable poliſh, and may deceive a good eye. This kind of ſelenites reſembles Muſcovy talc.

There is another ſort of artificial marble, formed by corroſive tincture, which penetrating into white marble to the depth of a line or more, imitate the various colours of other dearer marbles.

There is alſo a preparation of brimſtone in imitation of marble.

To do this, you muſt provide yourſelf with a flat and ſmooth piece of marble: on this make a border or wall, to encompaſs either a ſquare or oval table, which may be done either with wax or clay. Then having provided ſeveral ſorts of colours, as white-lead, vermilion, lake, orpiment, maſticot, ſmalt, Pruſſian blue, &c. melt on a ſlow fire ſome brimſtone, in ſeveral glazed pipkins; put one particular ſort of colour into each, and ſtir it well together; then having before oiled the marble all over within the wall, with one colour quickly drop ſpots upon it of larger and leſs ſize; after this, take another colour and do as before; and ſo on, till the ſtone is covered with ſpots of all the colours you deſign to uſe. When this is done, you are next to conſider what colour the maſs or ground of your table is to be: if of a grey colour, then take fine ſifted aſhes, and mix it up with melted brimſtone; or if red, with Engliſh red ochre; if white, with white-lead; if black, with lamp or ivory black. Your brimſtone for the ground muſt be pretty hot, that the coloured drops on the ſtone may unite and incorporate with it. When the ground is poured even all over, you are next, if judged neceſſary, to put a thin wainſcot board upon it: this muſt be done whilſt the brimſtone is hot, making alſo the board hot, which ought to be thoroughly dry, in order to cauſe the brimſtone to ſtick the better to it. When the whole is cold, take it up, and poliſh it with a cloth and oil, and it will look very beautiful. Smith's Laboratory, p. 248.

Marble, *Colouring of.* The colouring of marbles is a nice art, and in order to ſucceed in it, the pieces of marble, on which the experiments are tried, muſt be well poliſhed, and clear from the leaſt ſpot or vein. The harder the marble is, the better it will bear the heat neceſſary in the operation: therefore alabaſter, and the common ſoft white marble, are very improper to perform theſe operations upon.

Heat is always neceſſary for the opening of the pores of the marble, ſo as to render it fit to receive the colours; but the marble muſt never be made red-hot, for then the texture of the marble itſelf is injured, and the colours are burnt, and loſe their beauty. Too ſmall a degree of heat is as bad as too great: for, in this caſe, though the marble receives the colour, it will not be fixed in it, nor ſtrike deep enough. Some colours will ſtrike, even cold; but they are never ſo well ſunk in as when a juſt degree of heat is uſed. The proper degree is that which, without making the marble red, will make the liquor boil upon its ſurface. The menſtruums uſed to ſtrike in the colours muſt be varied according to the nature of the colour to be uſed. A lixivium made with horſe's or dog's urine, with four parts quick-lime, and one part pot-aſhes, is excellent for ſome colours; common ley of wood-aſhes does very well for others; for ſome, ſpirit of wine is beſt; and finally, for others, oily liquors, or common white wine.

The colours which have been found to ſucceed beſt with the peculiar menſtruums are theſe: ſtone-blue diſſolved in ſix times the quantity of ſpirit of wine, or of the urinous lixivium; and that colour which the painters call litmus, diſſolved in common ley of wood-aſhes. An extract of ſaffron, and that colour made of buckthorn berries, and called by the painters ſap-green, both ſucceed, well diſſolved in urine and quick-lime, and tolerably well in ſpirit of wine. Vermilion, and a fine powder of cochineal, ſucceed alſo very well in the ſame liquors. Dragon's blood ſucceeds very well in ſpirit of wine, as does alſo a tincture of logwood in the ſame ſpirit. Alkanet-root gives a fine colour, but the only menſtruum to be uſed for this is oil of turpentine; for

neither ſpirit of wine, nor any lixivium, will do with it. There is another kind of *ſanguis draconis*, called dragon's blood in tears, which, mixed with urine alone, gives a very elegant colour. Phil. Tranſ. N° 268, or Abridg. vol. iv. part ii. p. 205.

Beſide theſe mixtures of colours and menſtruums, there are ſome colours which are to be laid on dry and unmixed. Theſe are dragon's blood of the pureſt kind, for a red; gamboge for a yellow; green wax for a green; common brimſtone, pitch, and turpentine, for a brown colour. The marble for theſe experiments muſt be made conſiderably hot, and then the colours are to be rubbed on dry in the lump. Some of theſe colours, when once given, remain immutable; others are eaſily changed or deſtroyed. Thus the red colour given by dragon's blood, or by a decoction of logwood, will be wholly taken away by oil of tartar, and the poliſh of the marble not hurt by it.

A fine gold colour is given in the following manner: take crude ſal ammoniac, vitriol, and verdigris, of each equal quantities: white vitriol ſucceeds beſt, and all muſt be thoroughly mixed in fine powder.

The ſtaining of marble to all the degrees of red, or yellow, by ſolutions of dragon's blood or gamboge, may be done by reducing theſe gums to powder, and grinding them with the ſpirit of wine, in a glaſs mortar; but for ſmaller attempts, no method is ſo good as the mixing of a little of either of theſe powders with ſpirit of wine, in a ſilver ſpoon, and holding it over burning charcoal. By this means a fine tincture will be extracted, and with a pencil dipped in this, the fineſt traces may be made on the marble, while cold, which, on the heating of it afterwards, either on ſand, or in a baker's oven, will all ſink very deep, and remain perfectly diſtinct in the ſtone. It is very eaſy to make the ground-colour of the marble red or yellow by this means, and leave white veins in it. This is to be done by covering the places where the whiteneſs is to remain with ſome white paint, or even with two or three doubles only of paper, either of which will prevent the colour from penetrating in that part. All the degrees of red are to be given to marble by means of this gum alone; a ſlight tincture of it, without the aſſiſtance of heat to the marble, gives only a pale fleſh-colour; but the ſtronger tinctures give it yet deeper; to this the aſſiſtance of heat adds yet greatly; and finally, the addition of a little pitch to the tincture gives it a tendency to blackneſs, or any degree of deep red that is deſired.

A blue colour may be given alſo to marble by diſſolving turnſol in a lixivium of lime and urine, or in the volatile ſpirit of urine; but this has always a tendency to purple, whether made by the one or the other of theſe ways. A better blue, and uſed in an eaſier manner, is furniſhed by the Canary turnſol, a ſubſtance well known among the dyers. This needs only to be diſſolved in water, and drawn on the place with a pencil: this penetrates very deep into the marble, and the colour may be increaſed by drawing the pencil, wetted afreſh, ſeveral times over the ſame lines. This colour is ſubject to ſpread and diffuſe itſelf irregularly; but it may be kept in regular bounds, by circumſcribing its lines with beds of wax, or any other ſuch ſubſtance. It is to be obſerved, that this colour ſhould always be laid on cold, and no heat given even afterwards to the marble; and one great advantage of this colour is, that it is therefore eaſily added to marbles already ſtained with any other colours, and it is a very beautiful tinge, and laſts a long time. Mem. Acad. Par. 1732.

This art has in ſeveral people's hands been a very lucrative ſecret, though there is ſcarcely any thing in it that has not at one time or other been publiſhed.

Kircher has the honour of being one of the firſt who publiſhed any thing practicable about it. This author meeting with ſtones in ſome cabinets ſuppoſed to be natural, but having figures too nice and particular to be ſuppoſed to be nature's making, and theſe not only on the ſurface, but ſunk through the whole body of the ſtones, was at the pains of finding out the artiſt who did the buſineſs; and on his refuſing to part with the ſecret on any terms, this author, with Albert Gunter, a Saxon, endeavoured to find it out; in which they ſucceeded at length very well. Their method is this: take aqua fortis and aqua regia of each one ounce, ſal-ammoniac one ounce, ſpirit of wine two drachms, about twenty-ſix grains of gold, and two drachms of pure ſilver; let the ſilver be calcined and put into a phial, and pour upon it the aqua fortis; let this ſtand ſome time, then evaporate it, and the remainder will firſt appear of a blue, and afterwards of a black colour; then put the gold into another phial, pour the aqua regia upon it, and when it is diſſolved, evaporate it as the former; then put the ſpirit of wine upon the ſal. ammoniac, and let it be evaporated in the ſame manner All the remainders, and many others made in the ſame manner from other metals diſſolved in their proper acid menſtrua, are to be kept ſeparate and uſed with a pencil on the marble. Theſe will penetrate without the leaſt aſſiſtance of heat, and the figure being traced with a pencil on the marble, the ſeveral parts are to be touched over with the proper colours, and this renewed daily till the colours have penetrated to the deſired depth into the ſtone. After this the maſs may be cut into thin plates, and every one of them will have the figure exactly repreſented on both ſurfaces, the colours never ſpreading. The niceſt method of applying theſe, or the other tinging ſubſtances, to marble that is to be wrought into any ornamental works, and where the back is not expoſed to view, is to apply the colours behind, and renew them ſo often till the figure is ſufficiently ſeen through the ſurface on the front, though it does not quite extend to it. This is the method that of all others brings the ſtone to a nearer reſemblance of natural veins of this kind. The ſame author gives another method to colour marble by vitriol, bitumen, &c. forming a deſign of what you like upon paper, and laying the ſaid deſign between two pieces of poliſhed marble; then cloſing all the interſtices with wax, you bury them for a month or two in a damp place. On taking them up, you will find that the deſign you painted on the paper has penetrated the marbles, and formed exactly the ſame deſign on them. Kircher's Mund. Subter. lib. viii. § 1. cap. 9.

Wallerius, in his Mineralogy, vol. ii. p. 128. recommends the laſt method of Kircher; and the firſt method is copied in the Phil. Tranſ., N° 7.

The art was practiſed by Mr. Bird, a ſtone-cutter at Oxford, before the year 1666; but his method is not recorded. Mr. Robert Chambers, of Minching Hampton, in Glouceſterſhire, diſcovered and practiſed a method of colouring marble, which he kept a ſecret. Mr. Da Coſta has publiſhed an account of experiments made on ſeveral pieces of marble ſtained by this artiſt. Phil. Tranſ. vol. li. art. 5. p. 30, &c.

Spots of oil ſtain white marble, ſo that they cannot be taken out. See STAINING *of Stones*.

MARBLE, *Poliſhing of*. The art of cutting and poliſhing marble was, of courſe, known to the ancients, whoſe mode of proceeding appears to have been nearly the ſame with that employed at preſent; except, perhaps, that they were unacquainted with thoſe ſuperior mechanical means which now greatly facilitate the labour, and diminiſh the expence of the articles thus produced. There are many celebrated manu-

factories of this kind generally called marble mills, on the continent, and also in Great Britain; but as the principle on which they proceed is nearly the same in all, it will suffice in this place to give the description of one or two of the latter. The following description, together with some preliminary observations, communicated by a person practically acquainted with this subject, relate to the manufactory of Messrs. Brown and Mawe at Derby.

An essential part of the art of polishing marble is the choice of substances by which the prominent parts are to be removed. The first substance should be the sharpest sand, so as to cut as fast as possible, and this is to be used till the surface becomes perfectly flat. After this the surface is rubbed with a finer sand, and frequently with a third. The next substance after the finest sand is emery of different degrees of fineness. This is followed by the red powder called tripoli, which owes its cutting quality to the oxyd of iron it contains. Common iron-stone powdered and levigated answers the purpose very well. This last substance gives a tolerably fine polish. This, however, is not deemed sufficient. The last polish is given with putty. After the first process, which merely takes away the inequalities of the surface, the sand employed for preparing it for the emery should be chosen of uniform quality. If it abounds with some particles harder than the rest, the surface will be liable to be scratched so deep as not to be removed by the emery. In order to get the sand of uniform quality, it should be levigated and washed. The hard particles, being generally of a different specific gravity to the rest, may by this means be separated. This method will be found much superior to that of sifting. The substance by which the sand is rubbed upon the marble is generally an iron plate, especially for the first process. A plate of an alloy of lead and tin is better for the succeeding processes, with the fine sand and emery. The rubbers used for the polishing, or last process, consists of coarse linen cloths, such as hop bagging, wedged tight into an iron plane. In all these processes, a constant supply of small quantities of water is absolutely necessary.

The sawing of marble is performed on the same principles as the first process of polishing. The saw is of soft iron, and is continually supplied with water and the sharpest sand. The sawing, as well as the polishing of small pieces, is performed by hand. The large articles, such as chimney-pieces and large slabs, are manufactured by means of machinery working by water or steam. We shall next give a description of this branch of manufacture in the large way, as carried on by Brown and Mawe at Derby, and in London, N° 149 Strand, who have justly attained great celebrity as workers of spar and marble into different ornaments.

Fig. 1. *Plate* XXIII. *Miscellany*, is a side view of a mill for sawing and polishing slabs of marble; *fig.* 2. being a ground plan of the same, and marked with corresponding letters. A B C is a frame of wood, suspended by the upright frames of wood, D, E, F, G, from the beams H, H, H, H, so as to be capable of an oscillatory motion. Motion is given to this frame by the rod I communicating with the crank O K, which is turned by water or steam.

This frame, being put in motion, gives motion to the saw frames L, L, M, M, and to the polishing arms N, P, Q, which work on the pivot P, and are pushed backwards and forwards by the connecting iron rods *n*, *n*. The saws are iron plates shaped like a common saw, and fastened into oblong rings by means of pins. These rings are put upon the cross bars E, E, *b*, *b*, and the saws are stretched tight by the screws *s*, *s*, *s*, and C. R, R, S, S, are four upright posts constituting a frame, in which are placed the blocks of marble to be sawn into slabs, which are at the same time to guide the frame of the saw. At each end of this frame there are a number of upright square bars of iron *i*, *i*, between which the saws pass which bars, act as conductors. The posts R, R, can be removed to a greater distance, so as to make the frame longer for receiving different sized blocks. The part T, to which the saw is attached on the moveable frame, slides upon the upright post A C. It is suspended by a rope, which goes over a pulley *c*, and is counterbalanced by the weight W. By this means the saw may be made to press upon its work with any degree of force. It will be evident that the moveable frame, from its pendulous motion, does not move in a straight line, but a curve. The sliding part T, therefore, serves to induce a rectilineal motion of the saw. The upright bars of iron *i*, *i*, and C, are of a size equal to or less than the thinnest slabs, so that the saws may be placed at different distances, according to the thickness of the slabs. In order to alter the saws for this purpose, nothing more is necessary than to loosen the screws *s*, *s*, &c. and shift the oblong rings which contain the saws.

The slabs of marble to be polished are laid upon the carriage *b*, so as to correspond with the rubber Q, which passes over it in the direction of its length. In order to extend the rubber to the other parts of the slab, the carriage, *b*, has a lateral motion, by means of four grooved wheels running upon the iron guiders let into the beams *g*, *g*. The endless screw *c*, in the main shaft, turns the wheel *r*. This gives motion to the lever *w*. *fig.* 2, by means of the crank *q*. The lever communicates with the crank *k*, and turns the wheel *l*, more or less of a revolution, according to the length of this crank, which can be altered at pleasure by shifting the temporary pin *e*. By this latter motion the wheel, *k*, works the ratch *v*, and gives the lateral motion to the carriage. By this means the whole of the surface is exposed to the action of the rubber. Round articles of spar, gypsum, and marble, are turned in the lathe with pointed instruments of hardened steel. The pieces to be turned are attached to a wooden chock by means of cement. The gypsum is very soft, and turns with great facility. The fluor spar and marble require the tool to be very hard, while the part to be turned requires a constant supply of water, which drops from a vessel above. After the articles are turned into the given shape, they are dressed with sand and emery, and afterwards polished with tripoli and putty.

Small specimens for collections of marbles are generally polished upon a lap, which runs in a lathe. These laps, however, ought to run with the axis perpendicular to the horizon, the face of the lap being truly flat and horizontal. The lap used for the first process should be of iron; the second of an alloy of lead and tin; and the third, which is for polishing, should be of iron with pitch. By means of some auxiliary machinery, a number of pieces might be polished in this way at once, which would save much manual labour. Small pieces of marble may also be polished on the large machine, by cementing them with plaster on the surface of a large slab. By being placed on the same level, the large rubber sweeps them all at once.

The marble mill in the neighbourhood of Kilkenny, in Ireland, mentioned under the article IRISH MARBLES, *supra*, and which was invented by alderman Collis, grandfather of the present proprietor, is remarkable for the simplicity of its structure, and for the powers it exerts. One wheel, ten feet diameter, with twelve floats or ladles, gives motion, by a crank at one end of its axis, to a frame containing twelve saws, which do the work of about twenty men. By a

crank at the other end, it moves a frame of five poliſhers, which do the work of about ten men. At this end Mr. Collis has lately fitted a frame beneath the poliſhers, with eight ſaws, to the motion of which he has found the power of the machine fully equal. This mill may be fairly ſaid to do the conſtant work of forty-two men daily. During the night the mill ſtopped, a conſtant attention being required to ſupply the ſaws with ſand, and to attend the poliſhers. The ſaws are made of ſoft iron, and laſt about a week; they are conſtantly ſupplied with water and ſand; the latter is taken out of the bed of the Nore, and waſhed till nothing remains, but very fine and pure ſiliceous particles. A ſaw cuts ten inches in a day, and twelve when the water is ſtrong; it would require two men to do the ſame with a hand ſaw. The marble taken from the mill is firſt poliſhed with a *cove-ſtone*, that is, a brown ſand-ſtone imported from Cheſter, and which takes its name from being uſed in chimney coves. It is afterwards poliſhed by a *hone-ſtone*, which is a piece of ſmooth nodule of the argillaceous iron ore, found in the hills between Kilkenny and Freſhford. It receives the laſt poliſh in the mill with rags and putty. By means of this mill, the marble is ſo eaſily worked as to be ſold at a very moderate price.

A great improvement in cutting marble and other ſtones, but particularly columns by machinery, was invented in Ireland by the late ſir George Wright, bart., who procured a patent for it. By this a number of hollow columns can be cut from a ſolid block, each decreaſing in ſize, ſo that nothing of the ſtone is loſt, except what is converted into duſt by the ſaw.

Masonry

MASONRY is the art of preparing and combining ftones, fo as to tooth or indent them into each other, and form regular furfaces, either for fhelter, convenience, or defence; as the habitations of men, animals, the protection and fhelter of goods, &c.

The tools employed by the mafon are different in different countries, according to the quality of the ftone.

In London, the value of ftone occafions it to be cut into fcantlings by a faw, and the operation is done by the labourer; in different parts of the country where ftone abounds, it is divided into fmaller fcantlings by means of wedges. Hard ftone and marble are reduced to a furface by a mallet and chiffel.

The principal implements ufed in London for hewing ftones are the mallet and tools. The form of mafons' tools, which are ufed by the percuffive blows of the mallet, is that of a wedge; the cutting edge is the vertical angle. The material out of which fuch tools are made is iron, except the end which enters the ftone, which is of fteel. The end of the tool which is ftruck by the mallet is a fmall portion of a fpheric furface, and projects on all fides beyond the adjoining part or hand hold, which increafes in magnitude towards the middle of the tool, and thence tapers forward, in the form of a wedge or pyramid, to the entering or cutting edge. The other tools ufed by the mafon are, a level, a plumb rule, a fquare, a bevel, and rules both ftraight and circular, of various defcriptions, for trying the furfaces in the progreffive ftate of the work.

The tools ufed in London, in fucceffion, to work the face of a ftone, are, the point, the inch tool, the boafter, then the broad tool. The operation of working with the point is called *pointing*, and that with the boafter is called *boafting*. The operation of the point leaves the furface in narrow furrows, with rough ridges between them. The inch tool is ufed in cutting away the ridges, and the boafter in making the furface of the work nearly fmooth. The point is in breadth, at the entering part, from ¼th to ⅜ths of an inch, the boafter 2 inches wide, and the broad tool 3½ inches at the cutting edge. In the ufe of the tool, the cutting edge is always perpendicular to the fame fide of the ftone. There are two kinds of operations performed by it: fuppofe the impreffion made by the whole breadth of the tool, at the cutting edge, to be called a cavity. In one operation, the fucceffive cavities follow one another in the fame ftraight line, until the breadth or length of the ftone is exhaufted; then fucceffive equidiftant parallel lines are repeated in the fame manner, until the whole furface of the ftone has been gone over by the tool. This manner of hewing is called *ftroking*, which is a kind of fluted furface. In the other operation, every fucceffive cavity is repeated in new equidiftant lines throughout the length or breadth of the ftone, then a new feries of cavities is again repeated throughout the length or breadth of the ftone, and thus until the whole breadth or length of the ftone is exhaufted. This mode is called *tooling*.

Tools for working cylindrical and conical parts of mouldings are of all fizes, from ¼th part of an inch upwards; but thofe for working convex mouldings are generally half an inch broad, unlefs in confined fpaces, where fuch breadth cannot be admitted.

A ftone is taken, for the greater part, out of winding with points, and entirely with the inch tool.

In London, the facings of buildings made with fquared ftone, are either ftroked, tooled, or rubbed.

In the country, where the faving of ftone by the ufe of the faw is not a compenfation for the lofs of time taken up in fawing, the operation is entirely performed by the mallet and chiffel.

When ftones are very unfhapely previous to the operation of hewing, a ftone ax, jedding ax, fcabbling hammer, or cavil, is ufed in order to bring the ftone nearly to a fhape: one end of the jedding ax is flat, and is ufed for knocking off the very protuberant angular parts when lefs than right angles, the other end is pointed for reducing the different furfaces nearly to the intended form.

In fome parts of the country, different fancies of hewn furfaces are indulged, as herring-bone work: this is forming the furfaces of the ftones by zig-zag lines parallel to each other.

In Scotland, befides what has already been noticed in hewn work, are other kinds denominated droved, broached, and ftriped. Droving is the fame as that called random tooling in England, or boafting in London; and the chiffel for broaching is called a punch, and is the fame as that called a point in England. Broached work is firft droved and then broached, as the work cannot be done regularly at once with the punch. Striped work muft alfo be firft droved and then ftriped. Hence, of thefe three kinds of furfaces, the droved is the cheapeft. Though broaching is fometimes performed without droving, it is never fo regular; and befides, the furface is generally full of inequalities. It muft be obferved, however, that workmen in general do not take the fame pains to drove the face of a ftone which is to be afterwards broached, as in that of which the droving is to remain the

final finifh: thefe fhould be noticed by the fuperintendant. Droving, broaching, and ftriping, are the terms ufed in Edinburgh and Glafgow, and in the fouth of Scotland. In Aberdeen, where the ftone is very hard, being a kind of granite, the fame operations cannot be employed. Inftead of them they ufe a fcabbling hammer, by which they pick the ftone until the furface has nearly acquired its intended form. This manner of dreffing the furface for the ftone facing of a building is called *nidged work*, and the operation *nidging*. The term rubbed work is applied where the furface is fmoothed by means of fand or grit ftone.

Various curved rules, or templets and guages, are alfo employed in hewn work. The tools ufed in fetting or building are, a line and line pins, the level, the plumb rule, and rules of various defcriptions, as alfo templets for circular work.

Marbles are polifhed by firft being rubbed with grit-ftone, then with pumice-ftone, and laftly with emery or calcined tin.

The chief ftone ufed in London is Portland, which comes from the ifland of Portland in Dorfetfhire. It is ufed for public edifices, not only in ornaments, mouldings, and ftrings, but in all the exterior parts. In private buildings, where brick-work predominates, it is ufed in ftrings, window fills, balufters, fteps, copings, &c. It muft be obferved, however, that under a great preffure it is apt to fplinter or flufh at the joints, and for this reafon the joints cannot be made fo clofe as many other kinds of ftone will admit of. When it is recently quarried it is foft, and works eafily, but acquires great hardnefs in length of time. The cathedral of St. Paul, Weftminfter bridge, and almoft every public edifice in London, are conftructed wholly, or in part, of Portland ftone.

Purbeck ftone comes from the ifland of Purbeck, in Dorfetfhire alfo. It is moftly employed in rough work, as fteps and paving.

Yorkfhire ftone is ufed where ftrength and durability are requifite, as in paving and coping.

Ryegate ftone is ufed for hearths, flabs, and copings.

In Edinburgh a very fine ftone called Craigleith, brought from a village of the fame name in the neighbourhood of this city, is that moft commonly ufed in the conftruction of their edifices. They have alfo very good ftone from the Hails quarry, but rather inferior in point of colour.

This Craigleith quarry produces two kinds of rock, one of a fine cream or buff colour, called the liver rock, which is almoft unchangeable, even though expofed in a building to the weather.

The city of Glafgow is built of various kinds of ftone, the beft of which are, the Poffel and the Lord Prefident's quarry: moft other kinds are not only perifhable, but liable to change their colour.

In the north of England, ftone fit for hewn work is chiefly of a reddifh colour. There is a very good white ftone, however, in the vicinity of Liverpool, of which feveral of the public buildings are conftructed.

All the ftone fit to be fquared, or fquared and rubbed fmooth, for the ufe of building, is moftly compofed of fand. The ftone ufed for the fame purpofe in the fouth of England is, in fome parts, entirely chalk, and in other parts limeftone. The Bath and Oxfordfhire ftone has fo little grit in its texture, as to be wrought into mouldings with planes, as in joinery, and the furfaces are finifhed with an inftrument called a *drag*.

Marbles, with regard to their contexture and variegation of colour, are almoft of infinite variety: fome are black, fome white, fome of a dove colour, and others beautifully variegated with every kind of rich colour. The beft kind of white marble is that called ftatuary, and when cut into thin flices becomes almoft tranfparent, which property the others do not poffefs. The texture of marble, with regard to working, is not generally underftood even by the beft workmen, though upon fight they frequently know whether it will receive a polifh or not. Some marbles are eafily wrought, fome are very hard, and other kinds refift the tools altogether.

Mortar is another principal material ufed in cementing the ftones of a building. The reader who wifhes to obtain a full knowledge in this department of mafonry, may confult the article CEMENT, where he will receive fatisfactory information

Wherever it is intended to build upon, the ground muft be tried with an iron crow or with a rammer: if found to fhake it muft be pierced with a borer, fuch as is ufed by well diggers; and if the ground proves to be generally firm, the loofe or foft parts, if not very deep, muft be excavated until a folid bed appears.

If the ground proves foft in feveral places to a great depth under apertures, and firm upon the fcite of the piers, turn inverted arches under the apertures, fo that if the foundation fink, the arches will refift the re-action of the ground, then the whole wall will fink uniformly or defcend in one body. Should the ground be even of an uniform texture, it is always eligible to turn inverted arches under apertures, wherever there is a part of a wall carried up from the foundation to the fill of that aperture: it is from neglecting this circumftance that the fills of windows in the ground ftories of buildings are frequently broken; indeed it is feldom or never otherwife.

Arches adequate to this purpofe fhould rather be of a parabolic form than circular, the figure of the parabola being better adapted to preferve an equilibrium than the arc of a circle, which is of uniform curvature. If unfortunately the foft parts of the ground prove to be the fcite of the piers, and, confequently, the hard places under the apertures, build piers under the apertures, and fufpend arches between the piers with their concave fide towards the trench as ufual.

For more information upon this fubject, the reader will refer to the article FOUNDATION.

In walling, the bedding joints have moft commonly a horizontal pofition in the face of the work, and this difpofition ought always to take place when the top of the wall terminates in an horizontal plane or line. In bridge building, and in the mafonry of fence walls upon inclined furfaces, the bedding joints on the face fometimes follow the upper furface of the wall or terminating line.

The footings of ftone walls ought to be conftructed of large ftones, which, if not naturally nearly fquare, fhould be reduced by the hammer to that form, and to an equal thicknefs in the fame courfe; for if the beds of the ftones in the foundation taper, the fuperftructure will be apt to give way, by refting upon mere angles or points with inclined beds inftead of horizontal. All the vertical joints of any upper courfe fhould break joint, that is, they fhould fall upon the folid part of the ftones in the lower courfe, and not upon the joints.

When the walls of the fuperftructure are thin, the ftones which compofe the foundation may be fo difpofed that their length may reach acrofs each courfe, from one fide of the wall to the other. In thicker walls, where the difficulty is greater in procuring ftones of fufficient length to reach acrofs the foundation, every fecond ftone in the courfe may be a whole ftone in the breadth, and each interval may confift of two ftones of equal breadth, that is, placing header and ftretcher alternately. But when thofe ftones cannot be had

conveniently, from one ſide of the wall lay a header and ſtretcher alternately, and from the other ſide lay another ſeries of ſtones in the ſame manner, ſo that the length of each header may be two-thirds, and the breadth of each ſtretcher one-third of the breadth of the wall, and ſo that the back of each header may come in contact with the back of an oppoſite ſtretcher, and the ſide of that header to come in contact with the ſide of the header adjoining the ſaid ſtretcher. In broad foundations, where ſtones cannot be procured for a length equal to two-thirds of the breadth of the foundation, build the work ſo that the upright joints of any courſe may fall on the middle of the length of the ſtones in the courſe below, and ſo that the backs of each ſtone in any courſe may fall upon the ſolid of a ſtone or ſtones in the courſe below.

The foundation ſhould conſiſt of ſeveral courſes, of which each ſuperior courſe ſhould be of leſs breadth than the inferior one, ſay four inches on each ſide in ordinary caſes, and the upper courſe project four inches on each ſide of the wall. The number of courſes muſt be regulated by the weight of the wall, and by the ſize of the ſtones of which the foundation conſiſts.

A wall which is built of unhewn ſtone is called a *rubble* wall, whether with or without mortar. Rubble work is of two kinds, courſed and uncourſed. Courſed rubble is that of which the ſtones are guaged and dreſſed by the hammer, and thrown into different heaps, each heap containing ſtones of the ſame thickneſs; then the maſonry is laid in courſes or horizontal rows, which may be of different thickneſſes. The uncourſed rubble is that where the ſtones are laid promiſcuouſly in the wall, without any attention to placing them in rows. The only preparation which the ſtones undergo, is that of knocking off the ſharp angles with the thick end of the ſcabbling hammer.

Walls are moſt commonly built with an aſhler facing and backed with brick or rubble work. Brick backings are common in London where brick is cheaper, and ſtone backing in the north of England and in Scotland where ſtone is cheaper. Walls faced with aſhler, and backed with brick or uncourſed rubble, are liable to become convex on the outſide from the greater number of joints, and from the greater quantity of mortar placed in each joint, as the ſhrinking of the mortar will be in proportion to the quantity, and therefore a wall of this deſcription is much inferior to one of which the *facing* and backing are of the ſame kind, and built with equal care, even though both ſides were uncourſed rubble, which is the worſt of all walling. Where the outſide of a wall is an aſhler facing and the inſide courſed rubble, the courſes of the backing ſhould be as high as poſſible, and ſet with thin beds of mortar. In Scotland, where ſtone abounds, and where perhaps as good aſhler facings are conſtructed as any in Great Britain, the backing of their walls moſt commonly conſiſts of uncourſed rubble, built with very little care. In the north of England, where the aſhler facings of walls are done with leſs neatneſs, they are much more particular in courſing of their backings. Courſed rubble and brick backings are favourable for the inſertion of bond timbers: but in good maſonry wooden bonds ſhould never be in continued lengths, as in caſe of fire or rot the wood will periſh, and the maſonry, being reduced by the breadth of the timber, will be liable to bend at the place where it was inſerted. When it is neceſſary to have wall timber for the faſtening of battens for lath and plaſter, the pieces of timber ought to be built with the fibres of the wood perpendicular to the ſurface of the wall, or otherwiſe in unconnected ſhort pieces not exceeding nine inches in length.

In an aſhler facing the ſtones generally run from twenty-eight to thirty inches in length, twelve inches in height, and eight or nine inches in thickneſs. Although both the upper and lower beds of an aſhler, as well as the vertical joints, ſhould be at right angles to the face of the ſtone, and the face bed and vertical joints at right angles to the beds in an aſhler facing, where the ſtones run nearly of the ſame thickneſs, it is of ſome advantage, in reſpect of bond, that the back of the ſtone be inclined to the face, and that all the backs thus inclined ſhould run in the ſame direction, as this gives a ſmall degree of lap in the ſetting of the next courſe; whereas if the backs were parallel to the front, there could be no lap where the ſtones run of an equal depth in the thickneſs of the wall. It is of ſome advantage likewiſe to ſelect the ſtones, ſo that a thicker one and a thinner one may follow each other alternately. The diſpoſition of the ſtones in the next ſuperior courſe, ſhould follow the ſame order as in the inferior courſe, and every vertical joint ſhould fall as nearly as poſſible in the middle of the ſtone below.

In every courſe of aſhler facing, with brick or rubble backing, *through* ſtones (as they are technically termed) ſhould be introduced, and their number ſhould be proportioned to the length of the courſe, and every ſuch ſtone of a ſuperior courſe ſhould fall in the middle of every two like ſtones in the courſe below: this diſpoſition of bonds ſhould be ſtrictly attended to in all long courſes. Some wallers, in order to ſhew or demonſtrate that they have introduced ſufficient bonds in their work, chooſe their bond ſtones of greater length than the thickneſs of the wall, and knock or cut off their ends afterwards. This method is far from being eligible, as the wall is not only liable to be ſhaken by the force applied to break the end of the ſtone, but the ſtone itſelf is apt to be ſplit.

In every pier where the jambs are courſed with the aſhler in front, every alternate jamb ſtone ought to go through the wall with its beds perfectly level. If the jamb ſtones are of one entire height, as is frequently the caſe when architraves are wrought upon them, and upon the lentil crowning them, in the ſtones at the ends of the courſes of the pier which are to adjoin the architrave jamb, every alternate ſtone ought to be a through ſtone; and if the piers between the apertures be very narrow, no other bond ſtones will be neceſſary in ſuch ſhort courſes. But where the piers are wide, the number of bond ſtones muſt be proportioned to the ſpace: through ſtones muſt be particularly attended to in the long courſes below and above windows.

Bond ſtones ſhould have their ſides parallel and of courſe perpendicular to each other, and their horizontal dimenſion in the face of the work ſhould never be leſs than the vertical one. All the vertical joints, after receding about three quarters of an inch from the face with a cloſe joint, ſhould widen gradually to the back, and thereby form hollow wedge-like figures for the reception of mortar and packing. The adjoining ſtones ſhould have their beds and vertical joints filled with oil putty from the face to about three quarters of an inch inwards, and the remaining part, of the beds with well prepared mortar. Putty cement will ſtand longer than moſt ſtones, and will even remain prominent, when the ſtone itſelf is in a ſtate of dilapidation, by the influence of the corroding power of the atmoſphere. It is true that in all newly built walls cemented with oil putty, the firſt appearance of the aſhler work is rather unſightly, owing to the oil of the putty diſſeminating itſelf into the adjoining ſtones, which makes the joints appear dirty and irregular: but this diſagreeable effect is removed in a year, or leſs; and if care has been taken to make the colour of the putty ſuitable to that of the ſtone, the joints will hardly

appear, and the whole work will seem as if one piece. This is the practice of Glasgow. In London and Edinburgh fine water putty is used instead of it.

All the stones of an ashler facing should be laid on their natural beds. From a neglect of this circumstance the stones frequently flush at the joints, and this disposition of the lamina sooner admits the corroding power of the atmosphere to take place.

In building walls or insulated pillars of very small horizontal dimensions, every stone should have its beds level and without any concavity in the middle: because if the beds are concave, when the pillars begin to sustain the weight of the fabric the joints will in all probability flush. It ought likewise to be observed that every course of masonry of such piers ought to consist of one stone.

Vitruvius has left us an account of the construction of the walls of the ancients, as follows. "The sorts of walls are the reticulated, *Plate* I. *fig.* 1, and the ancient, which is called the incertain, *fig.* 2. Of these the reticulated is the handsomest, but the joints are so ordered that all the parts of the courses have an infirm position; whereas in the incertain, the materials rest firmly one upon the other, and are interwoven together; so that they are much stronger than the reticulated, though not so handsome. Both sorts are formed of very small pieces, that the walls, being saturated with mortar, may endure the longer: for the stones, being of a porous and spungy nature, absorb the moisture from the mortar; and when there is an abundance of mortar, the wall, having more humidity, will not so soon decay, but will on that account be rendered more durable; for as soon as the humidity is extracted from the mortar by the suction of the stones, then the lime and sand separating the cement is dissolved, and the mortar no longer uniting the materials, the walls soon become ruinous. This may be observed in some tombs near the city, which are built with marble or hewn stone, and the internal parts rammed with rubble stones; the mortar being by length of time drained of its humidity by the suction of the stones, and the union of the joints being dissolved, they separate and fall to ruin.

"To avoid this error, the middle space (*fig.* 2.) must be strengthened with abutments of the red hewn stone or bricks, or common flints, built in walls two feet thick, and bound to the front with cramps of iron fixed with lead; for the work being thus built in a regular manner, and not laid in promiscuous heaps, will remain without defect; and being by the orderly arrangement of the courses and joints firmly united and bound together, it will not be liable to fractures, nor will the abutments suffer it to fall to decay. For this reason the walls of the Greeks are not to be despised; for though they do not use smooth or polished materials, yet where they discontinue the square stones, they lay the flints, or common hard stones, that they use, in the same manner as bricks are generally laid, bending the courses together with alternate joints, and thus make their works strong and durable.

"These walls they build in two manners; one is called *Isodomum* (*fig.* 3.), and the other *Pseudisodomum* (*fig.* 4.) Isodomum is when all the courses are of an equal thickness; and Pseudisodomum when they are unequal. Both these sorts are firm; first, because the stones themselves are of a compact and solid nature, and do not absorb the moisture from the mortar, but preserve its humidity to a great age; and, secondly, being situated in regular and level courses, the mortar is prevented from falling, and the whole thickness of the wall being united, it endures perpetually.

"Another sort is that which they call Emplecton, *fig.* 5 and 6.) which is also used by our villagers. The faces of the stones in this kind are smooth; the rest is left as it grows in the quarry, being secured with alternate joints and mortar; but our artificers, quickly raising a shell, which serves for the faces of the wall, fill the middle with rubble and mortar: the walls, therefore, consist of three coats, two being the faces, and one the rubble core in the middle, *figs.* 5 and 6. But the Greeks do not build in that manner; they not only build the facing courses regularly, but also use alternate joints throughout the whole thickness, not ramming the middle with rubble, but building it the same as the face, and of one united coat construct the wall: besides this, they dispose single pieces (A), which they call diatonos, in the thickness of the wall, extending from one face to the other, which bind and exceedingly strengthen the walls. Those, therefore, who would build works of long duration, must attend to these rules, and make use of such methods of building; for the smooth polish, and beautiful appearance of the stones, will not prevent the wall from being ruined by age."

An arch, in masonry, is a part of a building suspended over a given plan, supported only at the extremities, and concave towards the plan.

The supports of an arch are called the *spring walls*.

The whole of the under surface of the arch opposite to the plan is called the *intrados* of the arch, and the upper surface is called the *extrados*.

The boundary line, or lines of the intrados, or those common to the supports and the intrados, are called the *springing lines* of the arch.

A line extending from any point in the springing line on one side of the arch, to the springing line on the opposite side of the arch, is called the *chord* or *span* of the arch.

If a vertical plane be supposed to be contained by the span and the intrados of the arch, it is called the section of the hollow of the arch.

The vertical line drawn on the section from the middle of the spanning line to the intrados, is called the *height* of the arch, as also the middle line of the arch, and the part of the arch at the upper extremity of this line is called the *crown* of the arch.

Each of the curved parts on the top of the section, between the crown and each extremity of the spanning line, is called the *haunches* or *flanks* of the arch.

The section of almost every given arch used in building has the following properties: the upper part is one continued curve, concave towards the span, or two curves forming an interior angle at the crown, both concave towards the spanning line.

Every two vertical lines on the section equidistant from each extremity, and parallel to the middle line, are equal.

The above definitions and propositions not only apply to arches with level bases, but also to arches which stand upon inclined bases.

When the base of the section or spanning line is parallel to the horizon, the section will consist of two equal and similar parts, so that if one were conceived to be folded upon the other, the boundaries of both would coincide.

Arches, the intrados of which is the surface of a geometrical solid that would fill the void, are variously named, according to the figure of the section of that solid perpendicular to the axis, as *circular*, *elliptical*, *cycloidal*, *catenarian*, *parabolical*, &c.

Arches of the circular kind have two distinctions, *viz.* the semicircle, and those of segments less than a semicircle, are called *scheme* or *skene* arches.

There are alſo *pointed*, *compoſite*, *lancet*, or *Gothic* arches, which are formed in the face of the wall, or in ſections parallel thereto, with the intrados of the arch.

When the extremities of an arch riſe from ſupports at unequal heights, ſuch an arch is called a *rampant* arch.

When a vertical line is drawn upwards, through each extremity of the ſpanning line, ſo as to cut off equal and ſimilar parts of the intrados, the arch is called a *horſe-ſhoe* arch, or *Moreſque* arch. Hence, in this kind of arch, the ſpanning line is leſs than any other line or chord drawn parallel to the ſpan, but under the top of each ſaid vertical line.

When the upper line or ſide of an arch is parallel to the under line or ſide, the arch is called an *extradoſſed* arch.

A ſimple vault is an interior concavity extended over two parallel oppoſite walls, or over all the diametrically oppoſite parts of one circular wall. An arch or vault are frequently underſtood as ſynonimous; but the diſtinction which we ſhall here obſerve is, that an arch, though it may be extended over any ſpace, has a very narrow intrados, not exceeding four or five feet; whereas a vault may be extended to any limit more than four or five feet. Thus, we frequently ſay an arch in a wall, but we never ſay a vault in a wall; though nothing is more common than to ſay a vaulted apartment, a vaulted room, a vaulted cellar, &c. So that a vault, as ſir Henry Wotton has obſerved, is an extended arch; we ſhall therefore apply arch to the head of the aperture in a wall which ſhews curvilineal interſections with the faces of the wall, and the word vault to arched apartments. We frequently, however, call the ſtone-work ſuſpended over an apartment an arch as well as a vault, ſo that every vault is an arch, but every arch is not a vault.

The intrados of a ſimple vault is generally formed of the portion of a cylinder, cylindroid, ſphere, or ſpheroid, never greater than the half of the ſolid; and the ſpringing lines which terminate the walls, or where the vault begins to riſe, are generally ſtraight lines parallel to the axis of the cylinder or cylindroid, or the circumference of a circle or ellipſe.

A circular wall is generally terminated with a ſpherical vault, which is either hemiſpherical, or a portion of the ſphere leſs than a hemiſphere.

A vaulted apartment, ſurrounded by an elliptic wall, is generally covered with a ſpheroidal vault, which is either a hemiſpheroid, or a portion leſs than a hemiſpheroid.

A conic ſurface is ſeldom employed in vaulting; but when the vault is to have this kind of intrados, the intrados ſhould be the half of a cone with its axis in a horizontal poſition, or a whole cone with its axis in a vertical poſition.

All vaults which have a horizontal ſtraight axis are called ſtraight vaults.

Beſides what we have already denominated an arch, the concavities which two ſolids form at an angle are called an arch.

If one cylinder pierce another of a greater diameter, the arch is called a cylindro-cylindric arch; the cylindro being applied to the cylindric part which has the greater diameter, and the cylindric to that which has the leſs.

If a cylinder pierce a ſphere of greater diameter than the cylinder, the arch is called a ſphero-cylindric arch; and on the contrary, if a ſphere pierce a cylinder of greater diameter than the ſphere, the arch is denominated a cylindro-ſpheric arch.

If a cylinder pierce a cone ſo as to make a complete perforation through the cone, two complete arches will be formed, called cono-cylindric arches; and on the contrary, if a cone pierce a cylinder ſo as to make the interior concavity through the cylinder a complete conic ſurface, the arch is called a cylindro-conic arch.

If a ſtraight wall be pierced with a cylindric aperture quite through, two arches will be formed, called plano-cylindric arches

Every ſpecies of arches is thus denoted by two preceding words; the former ending in *o*, ſignifying the principal vault or ſurface cut through, and the latter in *ic*, ſignifying the kind of aperture which pierces the wall or vault.

When two cylindric vaults, or two cylindroidic vaults, or a cylindric and cylindroidic vault pierce each other, and alſo their axes, ſo that the diameter of each hollow may be the ſame when meaſured perpendicular to a plane paſſing through the axis of both ſurfaces, the figure ſo formed is called a *groin*: but for more particular information on this point, ſee the article GROIN.

The formation of ſtone arches, in various caſes, has always been looked upon as a moſt curious and uſeful acquiſition to the operative maſon, or to the architect, or other perſon who is appointed to ſuperintend the work. In order to remove the difficulties experienced in the conſtruction of cylindric or cylindroidic arches, both in ſtraight and circular walls, we ſhall here ſhew an example of each:

Firſt, let it be required to conſtruct a ſemi-cylindroidic arch cutting a ſtraight wall with its axis oblique to the ſurface of the wall, but parallel to the horizon.

Let A B C D (*Plate* II. *fig*. 1.) be the plan of the aperture, A D and B C being the plan of the jambs; and A B and D C the plan of the ſides of the wall: produce D A and C B to G and F: draw the ſtraight line I G M F E at right angles with A G and C F: biſect G F at M: draw M H K perpendicular to G F: make M H equal to the height of the intrados of the arch, and deſcribe the ſemi-ellipſis G H F, which is the ſection of the intrados of the arch: make G I, H K, and F E equal to the breadth of the beds of the arch ſtone, and deſcribe the ſemi-ellipſis I K E, which is the ſection of the extrados of the arch. Now ſuppoſe the diſtances between the joints around the intrados of the arch to be all equal, and all the joints to tend to the centre M; divide the ſemi-ellipſis into ſuch an odd number of equal parts, that each part may be in breadth equal to what is intended for the thickneſs of the ſtones at that part; produce E I to S, and extend the whole number of theſe parts from G to S; and through the points of diviſion draw lines perpendicular to G S, or parallel to A G. Through all the points of diviſion of the ellipſis G H F, draw lines parallel to G A to meet A B; then take the lengths of all the parts of the lines ſo drawn that are terminated by G F and A B as follows: *viz*. make the firſt line on the left of G A equal to the firſt on the right of G A, and the point *b* will be obtained; and the ſecond on the left of G A equal to the ſecond on the right of G A, and the point *c* will be obtained: proceed in this manner until all the other points are obtained; then a curve being drawn through all the points A, *b*, *c*, *d*, &c. to T, will give the one edge of the envelope of the intrados of the arch; and by producing the perpendiculars erected upon G S to the points *e*, *f*, *g*, &c. and making the ſeveral diſtances *b e*, *c f*, *d g*, &c. equal to A D or B C, the points D, *e*, *f*, *g*, &c. to U, will give the other edge of the envelope by tracing a curve through them; then A *b e d*, *b c f e*, *c d g f*, &c. are the ſoffits of the ſtones.

To find any bevel which the joints on the face of the arch makes with that on the intrados of the ſame. Let *p q* be one of the joints tending to the centre M of the ſection of the arch: with the radius M G deſcribe an arc G N O, cutting *p q* at N: draw N P parallel to G A, cutting A B at P: draw P Q parallel to F G, cutting G A at Q: draw M L parallel to G A, cutting A B at L, and join L O; then Q L M is the bevel required: in the ſame manner may all the remaining bevels be found.

Again, let *p q r s* be the ſection of an arch ſtone, then making two bevels, one to *q p s* and the other to *r s p*, will be all the bevels that are neceſſary for that ſtone. Having obtained the ſeveral bevels, we ſhall now proceed to work the arch ſtone, whoſe ſection is *p q r s*: firſt work the lower bed of the ſtone correſponding to the joint *p q*, then draw a line for the ſoffit, which work alſo by means of the bevel *q p s*; then guage the ſoffit to its breadth, and work the upper bed of the ſtone by means of the bevel *r s p*; then take the ſoffit mould from the envelope, and draw the ends of the ſtone which coincides with the faces of the wall; then with the face bevels Q L M, and V L M, work the face of the ſtone.

Note, that finding the bevels for half the arch will be ſufficient by reverſing them.

The other arch ſtanding upon D C ſhews the ends of the ſtones in the face of the wall; its boundaries are two ellipſes of equal height to thoſe of the ſection.

To conſtruct a cylindro-cylindric arch, or a cylindric arch in a cylindric wall, the axis of the aperture being at right angles with the axis of the cylindric wall. Let A B C D be the half plan of the wall, B C being half of the convex curve, A D half of the concave curve, C D the middle line of the aperture tending to the centre of the concentric circles which form the plan, and A B parallel to C D, being the jamb. Through C draw E F perpendicular to C D: make C E and C F half the breadth of the aperture: from the centre C, with the radius C E or C F, deſcribe the ſemicircle E G F, which will be the ſection of the intrados: produce C E and C F to H and I, making E H and F I each equal to the breadth of the beds, and deſcribe the ſemicircle H K I: divide the intradoſſal curve E G F into the number of parts anſwering to the number of arch ſtones, and proceed to find the envelope, as deſcribed, for the ſtraight wall, which will give the moulds for the ſoffits of the ſtones as before.

To find the curves of the ends of the beds upon the face of the arch. Let L M repreſent a joint: draw L N and M O perpendicular to H I, cutting the plan of the wall at N and O: draw N P parallel to C I, cutting M O at P: in L M take any number of points *t* and *y*, and draw *t s* and *y w* parallel to L N, cutting the plan at *s* and *w*, and N P at *r* and *v*: draw M Q, *t u*, *y x*, perpendicular to L N: make M Q, *t u*, *y x*, reſpectively equal to P O, *r s*, *v w*, and L *x u* Q will be the curve of the joint required, which gives the face line of the upper bed of the lower ſtone, and the face line of the lower bed of the upper ſtone. In the ſame manner all the other face lines of the beds are to be found. The templet muſt be cut in the ſhape of L M Q.

To form an arch ſtone. Firſt make one of the beds, then make the ſoffit, then form the other bed, then form the face lines of each bed, then run a draught round the three face lines, then between theſe work the face of the ſtone in lines perpendicular to the horizon. This will be eaſily found by drawing a vertical line upon the ſection of each ſtone.

It is only neceſſary to draw the moulds for one half of the arch, as the reverſing of them in their application gives the ſtones of the other half.

The joints of any arch whatever may be found in the ſame manner, provided that the planes of the beds interſect a vertical plane perpendicular to the curve in the middle of the aperture.

It is obvious, on finding the face lines of the beds, that the loweſt face line is the quickeſt, and part of the plan of the wall itſelf; the next face line is flatter, or has leſs curvature, and thus each ſucceſſive face line has leſs curvature as it comes nearer to the top, and if there were a joint in the top, the face line of the beds would be quite a ſtraight line. Indeed, the face lines of two or three courſes might be wrought with ſtraight edges, as the difference could hardly be perceived.

MASONRY.

PLATE

Fig. 2.

Incertain.

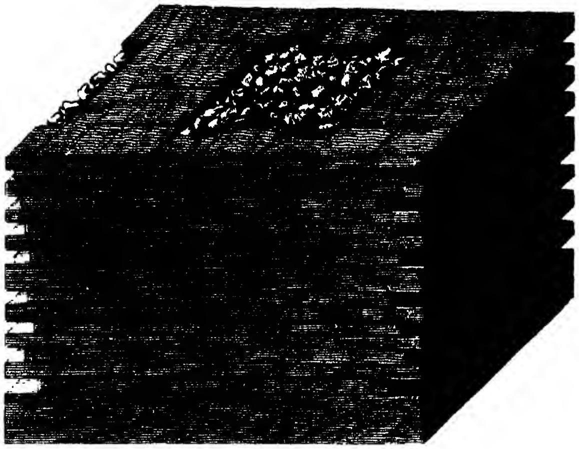

Fig. 1.

Reticulated.

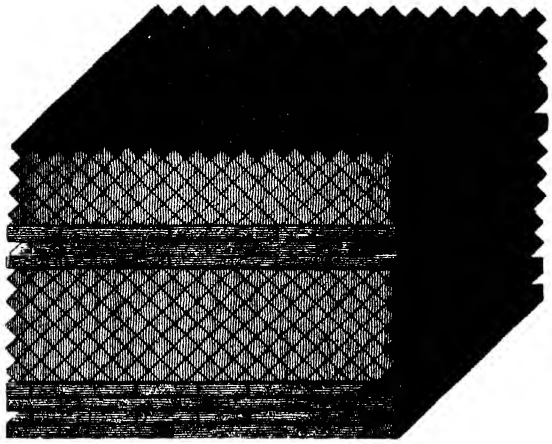

Fig. 4.

Pseudisodomum.

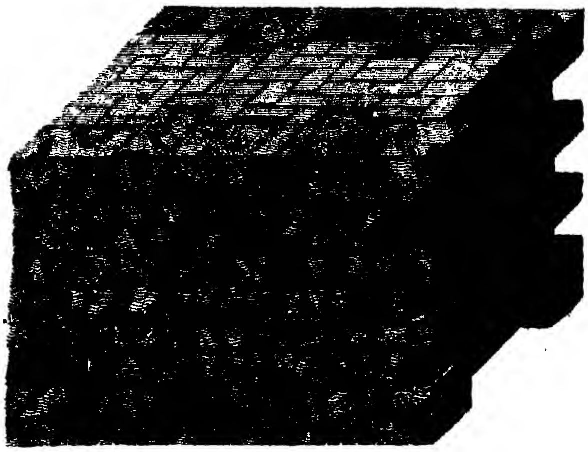

Fig. 3.

Isodomum.

Fig. 6.

Greek Emplection.

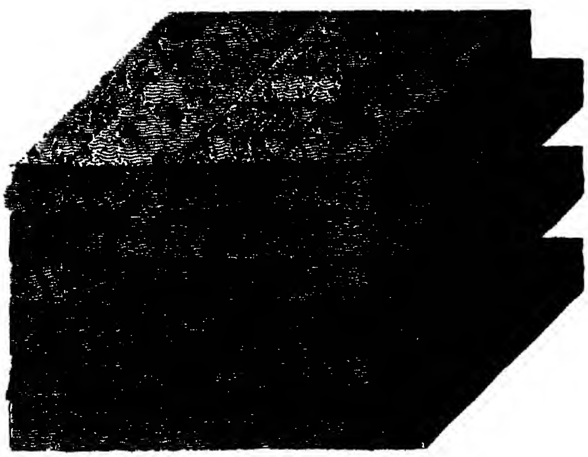

Fig. 5.

Roman Emplection.

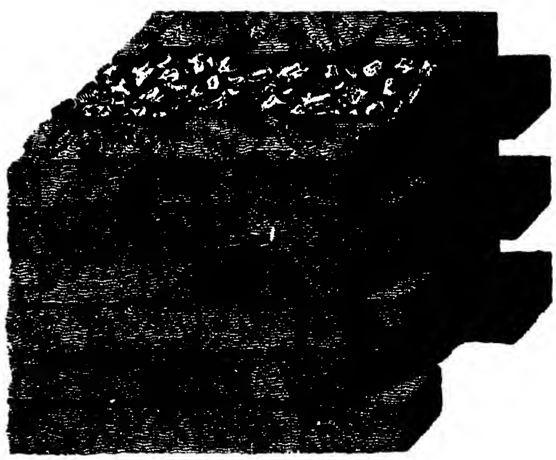

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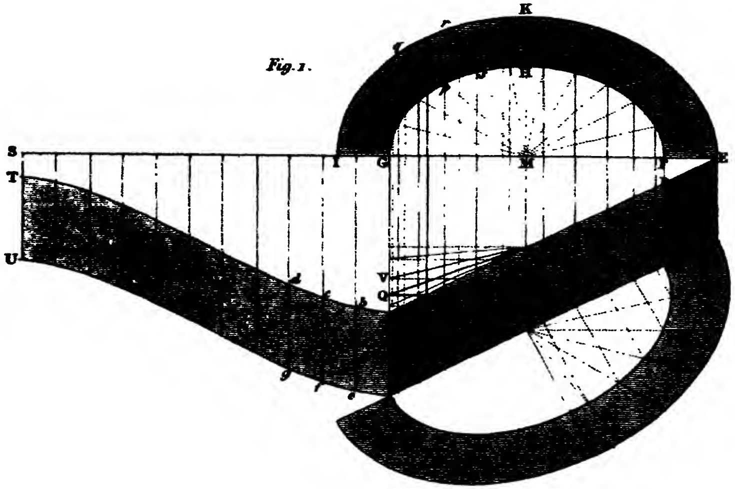
PLATE II.

ARCHES.

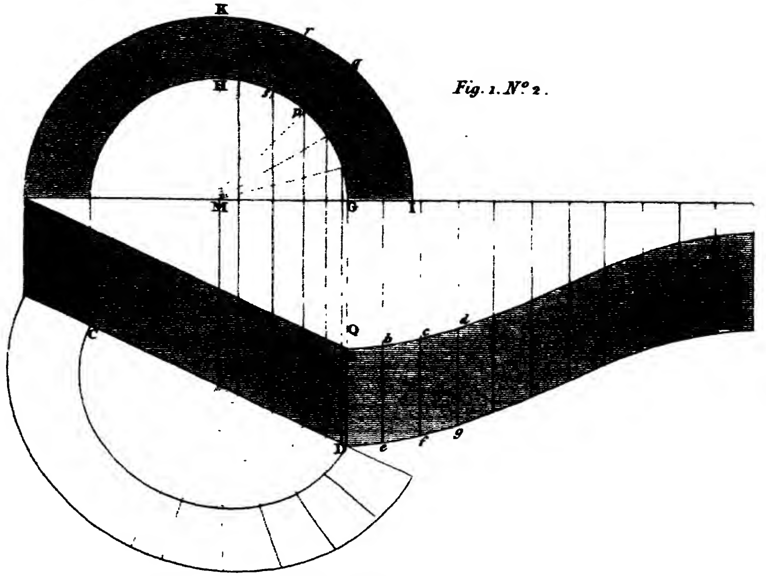
PLANO-CYLINDROIDIC ARCH

Fig. 1.



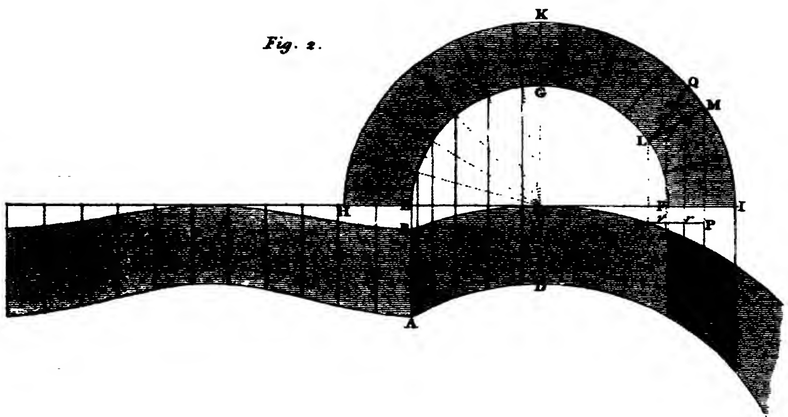
PLANO CYLINDRIC ARCH

Fig. 1. N° 2.



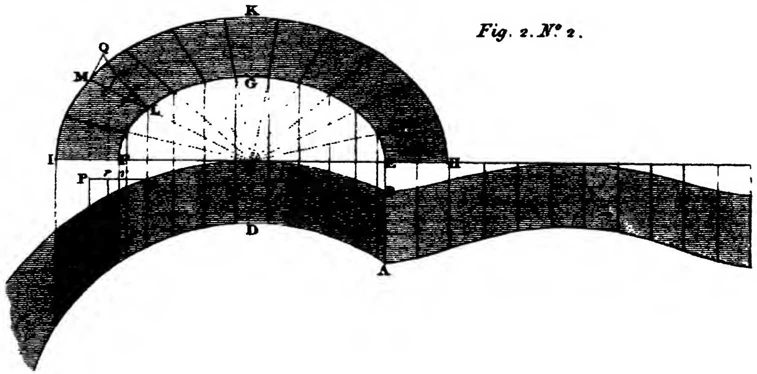
CYLINDRO - CYLINDRIC

Fig. 2.



CYLINDRO - CYLINDROIDIC

Fig. 2. N° 2.



P. Nicholson del.

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Mechanics

MECHANICS, that branch of practical mathematics which confiders motion and moving powers, their nature, laws, effects, &c. This term, in a popular fenfe, is applied equally to the doctrine of the equilibrium of powers, more properly called ftatics, and to that fcience which treats of the generation and communication of motion, which conftitutes dynamics, or mechanics ftrictly fo called. See STATICS, POWER, MOTION, and DYNAMICS.

This fcience is divided by Newton into practical and rational mechanics, the former of which relates to the mechanical powers, *viz.* the lever, balance, wheel and axis, pulley, wedge, fcrew, and inclined plane; and the latter, or rational mechanics, to the theory of motion; fhewing, when the forces or powers are given, how to determine the motion that will refult from them, and converfely when the circumftances of the motion are given, how to trace the forces or powers from which they arife.

Mechanics, according to the ancient fenfe of the word, confiders only the energy of *organa,* or machines. The authors who have treated the fubject of mechanics fyftematically have obferved, that all machines derive their efficacy from a few fimple forms and difpofitions, that may be given to the *organa,* which are interpofed between the agent and the refiftance to be overcome; and to thofe fimple forms they have given the name of mechanical powers, fimple powers, or fimple machines. See MECHANICAL *Powers.*

The practical ufes of the feveral mechanical powers were undoubtedly known to the ancients, but they were almoft wholly unacquainted with the theoretical principles of this fcience till a very late period; and it is therefore not a little furprifing that the conftruction of machines, or the inftruments of mechanics, fhould have been purfued with fuch induftry, and carried by them to fuch perfection. Vitruvius, in his 10th book, enumerates feveral ingenious machines which had then been in ufe from time immemorial. We find, that for raifing or tranfporting heavy bodies, they employed moft of the means which are at prefent commonly ufed for that purpofe, fuch as the crane, the inclined plane, the pulley, &c.: but with the theory or true principles of equilibrium they feem to have been unacquainted till the time of Archimedes. This celebrated mathematician, in his book of Equiponderants, confiders a balance fupported on a fulcrum, and having a weight in each fcale; and taking as a fundamental principle, that when the two arms of the balance are equal, the two weights fuppofed to be in equilibrio are alfo of neceffity equal, he fhews, that if one of the arms be increafed, the weight applied to it muft be proportionally diminifhed. Hence he deduces the general conclufion, that two weights fufpended to the arms of a balance of unequal length, and remaining in equilibrio, muft be reciprocally proportional to the arms of the balance; and this is the firft trace any where to be met with of any theoretical inveftigation of mechanical fcience. Archimedes alfo farther obferved, that the two weights exert the fame preffure on the fulcrum of the balance, as if they were directly applied to it; and he afterwards extended the fame idea to two other weights fufpended from other points of the balance, then to two others, and fo on, and hence, ftep by ftep, advanced towards the general idea of the centre of gravity, a point which he proved to belong to every affemblage of fmall bodies, and confequently to every large body, which might be confidered as formed of fuch an affemblage. This theory he applied to particular cafes, and determined the fituation of the centre of gravity in the parallelogram, triangle, trapezium, parabola, parabolic trapezium, &c. &c. To him we are alfo indebted for the theory of the inclined plane, the pulley, and the fcrew, befides the invention of a multitude of compound machines, of which, however, he has left us no defcription, and therefore little more than their names remain.

We may judge of the very imperfect ftate in which the theory of mechanics was at that time, by the aftonifhment expreffed by king Hiero, when Archimedes exclaimed, "Give me a place to ftand on and I will move the earth," a propofition which could have excited no furprife in any perfon poffeffing a knowledge of the fimple property of the lever. Of the theory of motion, however, it does not appear that even Archimedes poffeffed any adequate idea; the properties of uniform motion feem only to have engaged the attention of the ancients, and with thofe of accelerated and variable motion they were totally unacquainted: thefe were fubjects to which their geometry could not be applied, the modern analyfis being neceffary to bring this branch of the fcience to perfection.

From the time of Archimedes till the commencement of the fixteenth century, the theory of mechanics appears to have remained in the fame ftate in which it was left by this prince of Grecian fcience, little or no additions having been made to it during fo many ages; but about this time, Stevinus, a Flemifh mathematician, made known directly, without the introduction of the lever, the laws of equilibrium of a body placed on an inclined plane: he alfo inveftigated, with the fame fuccefs, many other queftions on ftatics, and determined the conditions of equilibrium between feveral forces concurring in a common point, which comes, in fact, to the famous propofition relating to the parallelogram of forces; but it does not appear, however, that he was at all aware of its confequences and application. In 1592, Galileo compofed a treatife on Statics, which he reduced to this fingle principle, *viz.* it requires an equal power to raife two different bodies to heights having the inverfe ratio of their weights; that is, whatever power will raife a body of two pounds to the height of one foot, will raife a body of one pound to the height of two feet. On this fimple principle he inveftigated the theory of the inclined plane, the fcrew, and all the mechanical powers, and Defcartes afterwards employed it in confidering the ftatical equilibriums of machines in general, but without quoting Galileo, to whom he had been indebted for the firft idea. To Galileo we are alfo indebted for the theory of accelerated motion, and its complete coincidence with the obferved phenomena of nature may be confidered as one of the greateft fteps made at one time in the fcience of phyfics. Since all bodies, faid this philofopher, are heavy, into whatever number of parts we divide any mafs, it follows, that its total weight is proportional to the number of material atoms of which it is compofed. Now the weight being thus a power always uniform in quantity, and its action never undergoing any interruption, it muft, in confequence, be continually giving new impulfes to a body, in every equal and fucceffive inftant of time, and while the body is falling, thefe impulfes are inceffantly accumulating, and remain in the body without alteration, the refiftance of the air alone being deducted, and hence the motion muft be accelerated by equal degrees.

Torricelli, a pupil of Galileo, profecuted the fubject after his mafter, and added feveral curious propofitions concerning projectiles, to thofe which the latter had previoufly inveftigated. Huygens confidered the motion of bodies along given curves, and demonftrated that the velocity of a heavy body, which defcends along any curve, is the fame at every inftant in the direction of the tangent, as it would have acquired by falling freely from a height equal to the correfponding vertical abfcifs. Then g this principle to inverted cycloid, the axis of w is vertical, he found

that a heavy body, from whatever part of the cycloidical arc it falls, always arrives at the lowest point of that arc in the same space of time. This very remarkable proposition includes what is commonly called the *isochronism* of the cycloid, and would alone have been sufficient to establish the fame of a geometrician. In 1661, Huygens, Wallis, and sir Christopher Wren, all discovered the true laws of percussion separately, and without any communication with each other, a proposition which Descartes had previously attempted, but failed in giving it a general solution. The finding of the centres of oscillation in compound bodies soon followed that relating to percussion, and here again Huygens equally distinguished himself by the accuracy and elegance of his solution; but as the principles which he employed were not well understood by the philosophers and mathematicians of that period, his investigations were much criticised at the time; but the honour of the discovery was finally attributed to him, and those of Descartes and Roberval admitted to be erroneous, or at least not sufficiently general. However, before the discovery of the fluxional calculus, there were many curious and interesting mechanical properties which the ancient geometry was incompetent to investigate, and which could never have been brought to light but by the assistance of this modern branch of analysis.

After the foundation of statics was laid by Archimedes, it was not difficult to discover the conditions of equilibrium in every particular case, and these had guided the genius of invention in a number of machines, but they were not yet reduced to a general and uniform principle.

Varignon undertook and accomplished this plan of combining them, by means of the theory of compound motions. He gave some sketches of this in 1687, in his Project of a new System of Mechanics, and he in some degree exhausted all the combinations of the equilibrium of machines, in his "General Mechanics," not published till after his death, in 1725. In 1695, la Hire published a "Treatise on Mechanics," the general object of which, like that of Varignon's, is the equilibrium of machines, beside which it contains various applications of machines to the arts, in which the author was well versed. He also subjoined a treatise on epicycloids, and their use in this science, particularly as relating to the forms of teeth in wheel-work. This is a beautiful theory, and is highly creditable to its author, who it appears from the testimony of Leibnitz was not la Hire, though he published it as such, but was due to the celebrated Danish mathematician Roemer, who had communicated it to Leibnitz twenty years before la Hire's work appeared. After this period, several elementary treatises on the subject of mechanics were published, without, however, adding much to the previous stock of knowledge, unless indeed we except that of Cormus, a work highly valuable for the strictness and perspicuity of its demonstrations.

At this time very little had been done with regard to the theory of variable motion; this now began to engage the attention of mathematicians, and opened an extensive field to their researches. Galileo, as we have seen, made known the properties of rectilinear and uniformly accelerated motions; Huygens had treated of curvilineal motion, which finally led to the beautiful theory of central forces in a circle, and which is equally applicable to motion in any curve, by considering them as infinite series of small arcs of a circle, agreeably to the idea which he himself had employed in his general theory of evolutes. The laws of the communication of motion, likewise sketched by Descartes, and farther pursued by Wallis, Huygens, and Wren, had made a new and very considerable step, by means of the solution which Huygens gave of the celebrated problem of the centres of oscillation. All these acquisitions, at first separate and in some measure independent of each other, having been reduced to a small number of simple, commodious, and general formulæ, by means of the analysis of infinites, the science of mechanics acquired fresh vigour, and was prosecuted with the most unbounded success. The problems relating to motion were reduced into two classes; the first comprising the general problem of the motion of a single body acted upon by any given powers; and the second, the motions which result from the action and re-action that several bodies exert on each other in any given manner.

In the motion of a single body, we observe that matter, being of itself passive, if once set in motion, must uniformly persevere in it; and that its motion can neither increase nor diminish, unless by the action of some external power, which may be either constant or variable. And hence arise two principles, that of *vis inertiæ* and that of compound motion; and on these are founded the whole theory of motion, rectilineal or curvilineal, constant or variable, according to a given law. By virtue of the *vis inertiæ*, motion at every instant is essentially rectilinear and uniform, setting aside resistance and every obstacle that might otherwise impede or change its direction; and by the nature of compound motion, a body exposed to the action of a given number of forces, all tending at the same time to change the quantity and direction of its motion, takes such a path through space that in the last instant it reaches the same point at which it would have arrived, had it successively and freely obeyed each of the forces proposed.

On applying these principles to rectilineal motions uniformly accelerated, we perceive, 1st, that in this motion, the velocities increasing by equal degrees, or proportionally to the time, the accelerating force must be constant, or incessantly give equal impulses to the moving body, and that, consequently, the final velocity is as the product of the accelerating force multiplied by the time. 2dly. Each elementary portion of space passed through being as the product of the corresponding velocity multiplied by the element of the time, the whole of the space passed through is as the product of the accelerating force multiplied by the square of the time; and these two properties equally take place for each elementary portion of any variable motion whatever. Thus in every rectilineal motion variable according to a given law, the increment of the velocity is as the product of the accelerating force into the element of the time, and the second fluxion of the space passed through is as the product of the accelerating force into the square of the element of the time. Now if to these principles we add that of compound motion, we shall arrive at the knowledge of all curvilineal motion whatever. In fact, whatever forces be applied to a body describing a curve, we may at each instant reduce these forces to two, the one acting in the direction of the tangent at any point of the curve, and the other perpendicular to it; the first produces an instantaneous rectilineal motion, to which the principle of *vis inertiæ* applies; and the second is expressed by the square of the actual velocity of the body, divided by the radius of curvature, agreeably to the theory of central forces in the circle, which equally reduces to the same principle the motion in the direction of the radius of curvature. Such were the general principles introduced into the science of mechanics by means of the modern analysis, and there seems to be no doubt that it was by pursuing this theory, Newton was led to those brilliant discoveries which he afterwards published in his "Principia" under a different form. In 1716, Hermann published his "De Phoronomia," in which he undertook to explain all that regards mechanics, both of

ſolids and fluids, that is to ſay, ſtatics, dynamics, hydroſtatics, and hydraulics; in which he employs the ſynthetic method, although, like Newton, he doubtleſs derived moſt of his reſults from analyſis, a circumſtance which frequently interrupts the unity and connection of his problems.

The Mechanics of Euler, publiſhed in 1736, contain the whole theory of rectilinear and curvilinear motion in an iſolated body, acted upon by any accelerating forces whatever, either in vacuo or in a reſiſting medium. The author has every where followed the analytical method, which, by reducing all the branches of this theory to uniformity, greatly facilitates the connection of it, and the whole is managed with an elegance and perſpicuity, of which, before this time, we had no example. As to the principles of mechanics by which he puts his problems into equations, he employs thoſe above mentioned.

This manner of laying the foundation of the calculation, however, though ſufficiently commodious, was not the only one that might have been employed, nor was it the moſt ſimple. For the forces and motions at every inſtant may be reſolved into other forces and motions parallel to fixed lines of given poſition in ſpace. In which caſe nothing more is neceſſary than to apply the equations of the principles of *vis inertiæ* to theſe motions and forces, by which means the theorem of Huygens may be avoided. This ſimple idea, which was firſt employed by Maclaurin in his "Treatiſe on Fluxions," threw new light on the theory of mechanics, and much facilitated the ſolution of various problems. When the body moves conſtantly in one plane, two fixed axes only are to be taken, which are ſuppoſed to be perpendicular to each other, for the ſake of greater ſimplicity; but when we are obliged, by the nature of the forces, to change the path continually in all directions, and to deſcribe a curve of double curvature, three axes are to be employed perpendicular to each other, or forming the edges of a right-angled parallelopipedon. But the problems relating to the communication of motion, commonly called *dynamic problems*, required new principles. Theſe, for inſtance, conſiſt in determining the motions that reſult from the percuſſion of ſeveral bodies; the centre of oſcillation of a compound pendulum; the motions of ſeveral bodies ſtrung upon a rod, which has a rotatory movement round a fixed axis; &c.

Now it is evident, that in all caſes of this kind the motion of the bodies is not the ſame as if the bodies were iſolated and at liberty, but that there muſt be a diſtribution of the forces among all the bodies forming one whole, ſo that the motion gained by ſome of them is loſt by others. The motion gained or loſt is always eſtimated by the product of the maſs into the velocity received or loſt, whether the communication or the loſs of motion be produced every inſtant by finite degrees, as in the ſhock of hard bodies, or whether the velocity change at each inſtant only by degrees infinitely ſmall, as in motion of ſeveral bodies ſtrung on a moveable rod, and generally in all caſes where forces act in the manner of gravitation.

When Huygens gave his ſolution of the problems of oſcillation, ſome unſkilful mathematicians attacked it in reviews. James Bernouilli defended it in the Leipſic Tranſactions for 1686, and undertook to give a direct demonſtration by means of the principle of the lever. At firſt, he conſidered only two equal weights faſtened to an inflexible rod devoid of gravity, which was in motion round an horizontal axis. Having then obſerved that the velocity of the weights, neareſt to the axis of rotation, muſt neceſſarily be leſs, and that on the other greater, than if each acted on the rod ſeparately, he concludes that the force loſt and the force gained balance each other, and that, conſequently, the product of the quantity of matter in one, into the velocity it loſes, and that of the other multiplied by the velocity it gains, muſt be inverſely proportional to the arms of the lever. This reaſoning is in fact accurate, only James Bernouilli miſtook in ſetting out, by conſidering the velocities of the two bodies as finite, inſtead of which he ſhould only have conſidered the elementary velocities, and compared them with the ſimilar velocities produced every inſtant by the action of gravitation. De l'Hôpital remarked this error, and in correcting it, he found the centre of oſcillation of the two weights, without departing in other reſpects from the principle of Bernouilli. In order then to proceed to a third weight, he united the former two at their centre of oſcillation, and combined this new weight with the third, as he had combined together the former two, and ſo on. But the propoſed union was a little precarious, and could not be admitted without a demonſtration. This led Bernouilli to revive his former ſolution, in order to extend it generally to any number of bodies, which he finally accompliſhed. His method conſiſts in reſolving the motion of each body at any given inſtant into two other motions, the one, that which the body actually takes; and the other, that which is deſtroyed, and in forming equations which expreſs the condition of equilibrium between the motions loſt; by which means the problem is brought under the general laws of ſtatics. The author applies this principle to ſeveral examples, and demonſtrates ſtrictly, and in the moſt evident manner, the propoſition which Huygens employed as the baſis of his ſolution. See Memoirs of the Academy of Sciences for 1703.

This ſolution of the problem of the centres of oſcillation, ſeemed to leave nothing to be deſired; yet, in 1714, it was brought forward again by John Bernouilli and Dr. Taylor, which were fundamentally the ſame. This occaſioned warm diſputes between them, as to the originality of their performances. Here, inſtead of the elementary weights of which the pendulum is compoſed, other weights are ſuppoſed to be ſubſtituted, in one and the ſame point, ſuch that their motion of angular acceleration, and their motion with reſpect to the axis of rotation, ſhall be the ſame, and the new pendulum oſcillate as the former. But theſe ſolutions are not conſidered ſo luminous as that of James Bernouilli, which was founded immediately on the laws of equilibrium. Leibnitz eſtimated the momenta of bodies by the maſs into the ſquare of their velocities, and John Bernouilli having adopted the ſame opinion, gave to the principles of Huygens, for the problem of the centres of oſcillation, the name of the principle of converſion of the *vires vivæ*, which it has retained, becauſe, in fact, in the motion of a ſyſtem of heavy bodies, the ſum of the products of the maſſes into the ſquares of the velocities remains the ſame, when the bodies deſcend conjointly, and when they afterwards aſcend ſeparately, with the velocities they acquired by their deſcent. This principle was alſo followed with ſucceſs in dynamical problems, by ſeveral able analyſts of the laſt century; but as it gives only a ſingle equation, from which the velocity or the time muſt afterwards be expunged, the ſecond object was attained by different means.

John Bernouilli employed for this purpoſe the principle of *tenſions*; Euler, that of *preſſures*; Daniel Bernouilli, that of *virtual power*, which a ſyſtem of bodies has of re-eſtabliſhing itſelf in its former ſtate; and in certain caſes both he and Euler made uſe of the conſtant quantity of circulatory motion round a fixed point. And when at length all the differential, or fluxional equations of the problem

were eftablifhed, it remained only to refolve them, which was of courfe the leaft difficult part of their inveftigations.

The principle which had been employed by James Bernouilli, in the folution of the problem relating to the centre of ofcillation, was generalized by D'Alembert; he fhewed, that in whatever manner the bodies of one fyftem act upon each other, their motions may always be refolved at every inftant into two forts of motions, thofe of the one being deftroyed in the fucceffive inftant, but the other retained; and that the motions retained are neceffarily known from the conditions of the equilibrium between the motions deftroyed. This general principle applies to all the problems of dynamics, and at leaft reduces all their difficulties to thofe of the problems of fimple ftatics; and renders ufelefs that of the converfion of *vires vivæ*. By this means D'Alembert has refolved a number of very beautiful and very difficult problems, fome of which were abfolutely new, as, for example, that relating to the preceffion of the equinoxes. Thefe general principles were firft developed by D'Alembert in 1743, but they were more fully treated of in his Treatife of Dynamics, publifhed in 1749; a truly interefting and original work, highly creditable to the talents of this celebrated author. The fcience of dynamics having thus gradually attained a high degree of perfection, was ftill farther enriched, in 1765, by an important difcovery, which is due to Segner; who has fhewn in a fhort paper entitled "Specimen Theoriæ Turbinum," *that if a body, of any fize and figure, after rotatory or gyratory motions in all directions have been given to it, be left entirely to itfelf, it will always have three principal axes of rotation;* that is, that all the rotatory motions, by which it is affected, may conftantly be reduced to three, which are performed round three axes perpendicular to each other paffing through the centre of gravity or inertiæ of the body, and always preferving the fame pofition in abfolute fpace, while the centre of gravity is at reft, or moves uniformily in a right line; the pofition of thefe three axes being determined by an equation of the third order. This theory, which its author had not fufficiently developed, Albert, the fon of the celebrated Euler, treated at length in his paper "On the Stowage of Ships," which fhared the prize of the Academy of Sciences at Paris for 1761, as did likewife his father, according to the fame method, in the Memoirs of the Academy at Berlin for 1759, and in his work entitled "Theoria Motus Corporum rigidorum, 1765." Laftly, D'Alembert fhewed in his "Mathematica Opufcula," vol. iv. publifhed in 1768, that the folution of the problem was deducible from the formulæ which he had given in a memoir for determining the motion of a body of any figure, acted upon by any forces whatever, printed in vol. i. of his Opufcula in 1761. The knowledge of thefe motions of free rotation round three principal axes, naturally led to the determination of the motion round any variable axes whatever; and hence, if we confider the body to be acted upon by any given accelerating forces, we muft begin with determining the rectilinear or curvilinear motion of the centre of gravity abftractedly from all rotatory motion, and then combining this progreffive motion with the rotatory motion of a given point of the body round a variable axis, we fhall know at every inftant the compound motion of this point in abfolute fpace. On thefe principles Euler has refolved many curious and interefting problems relating to dynamics, and the fame have been fince farther proved by fubfequent mathematicians. (Boffut's Hift. Math.) We have thus given a fketch of the hiftory and fucceffive improvements of the fcience of mechanics, which is all that is neceffary under the prefent article, as the particular branches connected with this fubject are treated of feparately under their refpective heads in the different articles of this work. But as we have only directed our attention to the more prominent parts of the hiftory, the works to which our references have been made are very limited. It remains, therefore, before we conclude this article, to enumerate fome of the principal writers on mechanics, or on particular branches of it, which are as follows, *viz.*

Newton, in his "Principia;" Guido Ubaldus, in his "Liber Mechanicorum;" Torricelli, "Libri de Motu Gravium naturalitis Decendentium et Projectorum;" Balianus, "Tractatus de Motu naturali Gravium;" Huygens, "Horologium Ofcillatorium," and "Tractatus de Motu Corporum ex Percuffione;" Leibnitz, "Refiftentia Solidorum," in Acta Euroditus, ann. 1684; Guldinus, "De Centro Gravitatis;" Wallis, "Tractatus de Mechanica;" Varignon, "Projet d'une Nouvelle Mechanique," and his papers in the Memoires Acad. ann. 1702; Borelli, "Tractatus de Vi Percuffionis, de Motionibus naturalibus, &c.;" De Chales, "Treatife on Motion;" Pardies, "Difcourfe on Local Motion;" Parent, "Elements of Mechanics and Phyfics;" Cafatus, "Mechanica;" Oughtred, "Mechanical Inftitution;" Robault, "Tractatus de Mechanica;" Lamy, "Mechanique;" Keil, "Introduction to true Philofophy;" De la Hire, "Mechanique;" Mariotte, "Tracti du Choc du Corps;" Ditton, "Laws of Motion;" Hermann, "Phoronomia;" Gravefande, "Phyfics;" Euler, "Tractatus de Motu;" Mufchenbroeck, "Phyfics;" Boffu, "Mechaniques;" La Grange, "Mechanique Analytique;" Atwood, "On Motion;" Prony, "Architeture Hydraulique," and "Mechanique Analytique;" Francear, "Mechanique;" Gregory, "Mechanics in Theory and Practice," &c. &c. to which may be added the names of Nicholfon, Enfield, Wood, Fergufon, Young, and Marat. For thofe works which relate principally to the defcription of machinery, fee the article MACHINE.

MECHANICAL, fomething that relates to mechanics, or is regulated by the nature and laws of motion.

In which fenfe we fay mechanical powers, mechanical properties or affections, mechanical principles, reafoning, knowledge, &c.

MECHANICAL *Affections*, are fuch properties in matter, as refult from their figure, bulk, and motion.

MECHANICAL *Caufes*, are thofe founded on fuch affections.

MECHANICAL *Force*. See FORCE.

MECHANICAL *Solutions*, are accounts of things on the fame principles.

MECHANICAL *Philofophy*, is the fame with what we otherwife call the *corpufcular philofophy; viz.* that which explains the phenomenon of nature, and the operations of corporeal things, on the principles of mechanics; *viz.* the motion, gravity, figure, arrangement, difpofition, greatnefs, or fmallnefs of the parts which compofe natural bodies. See CORPUSCULAR.

MECHANICAL *Powers*, (fo called,) are thofe machines which are ufed for raifing greater weights, or overcoming greater refiftances than could be effected by the natural ftrength without them; the power of ftrength being applied to one part of the machine, and another part of the machine applied to the weight or refiftance.

There are two principal problems that ought to be refolved in treating of each of them.

The firft is, to determine the proportion which the power

and weight ought to have to each other, that they may juſt ſuſtain one another, or be in equilibrio.

The ſecond is, to determine what ought to be the proportion of the power and weight to each other in a given machine, that it may produce the greateſt effect poſſible, in a given time.

As to the firſt problem, this general rule holds in all powers; ſuppoſe the engine to move, and reduce the velocities of the power and weight to the reſpective directions in which they act; find the proportions of thoſe velocities; then if the power be to the weight as the velocity of the weight is to the velocity of the power; or, which amounts to the ſame thing, if the power multiplied by its velocity, gives the ſame product as the weight multiplied by its velocity, this is the caſe wherein the power and weight ſuſtain each other, and are in equilibrio; ſo that in this caſe the one would not prevail over the other, if the engine was at reſt; and if it is in motion, it would continue to proceed uniformly, if it were not for the friction of its parts, and other reſiſtances.

The ſecond general problem in mechanics is, to determine the proportion which the power and weight ought to bear to each other, that when the power prevails, and the machine is in motion, the greateſt effect poſſible may be produced by it in a given time. It is manifeſt, that this is an enquiry of the greateſt importance, though few have treated of it. When the power is only a little greater than that which is ſufficient to ſuſtain the weight, the motion is too ſlow; and though a greater weight is raiſed in this caſe it is not ſufficient to compenſate the loſs of time. When the weight is much leſs than that which the power is able to ſuſtain, it is raiſed in leſs time; and this may happen not to be ſufficient to compenſate the loſs ariſing from the ſmallneſs of the load. It ought, therefore, to be determined when the product of the weight, multiplied by its velocity, is the greateſt poſſible; for this product meaſures the effect of the engine in a given time, which is always the greater in proportion as the weight which is raiſed is greater, and as the velocity with which it is raiſed is greater. For other conſiderations neceſſary to be regarded in the conſtruction and uſe of machines, we refer to the articles Machine and Machinery.

The ſimple machines by which power is gained, are ſix in number, *viz.* the *lever*, the *wheel and axle*, or *axis in peritrochio*, the *pulley* (or rather ſyſtem of pullies), the *inclined plane*, the *wedge*, and the *ſcrew*. Of theſe, all ſorts of mechanical engines conſiſt; and in treating of them, ſo as to ſettle their theory, we muſt conſider them as mechanically exact, and moving without friction. Although theſe machines are treated of at large under their proper heads, it may not be amiſs to give a ſhort account of them all here.

1. A *lever* is an inflexible bar, turning upon a ſupporting prop as its centre of motion, which muſt be firm enough to bear the lever and the weight with which it is charged. There are three kinds of levers, and in each of them the velocity of each point is directly as its diſtance from the prop.

A lever is ſaid to be of the firſt kind when the prop is between the weight and the power. Here the power and weight balance each other, when the power is in proportion to the weight as the diſtance of the weight from the prop is to the diſtance of the power from it; ſo that if a weight be twenty pounds, and at one foot from the prop, a power of one pound at twenty feet from the prop will balance the weight, ſuppoſing the lever itſelf to have no weight. To this ſort of lever may be reduced all iron crows, ſciſſars, pinchers, candle-ſnuffers, and the like.

A lever is ſaid to be of the ſecond kind, when the weight is between the prop and the power. Here the lever and weight balance each other when the power is in proportion to the weight as the diſtance of the weight from the prop is to the diſtance of the power from it. Of this ſort are doors turning on hinges, oars, and ſuch knives as are fixed at the point.

A lever is ſaid to be of the third kind when the power is between the weight and the prop. In this, the power and weight balance each other, when the power is in proportion to the weight, as the diſtance of the weight from the prop is to the diſtance of the power from it: but this lever is never uſed where power is wanted to be gained; for in it, the intenſity of the power applied, muſt always exceed the intenſity of the weight to be raiſed, or reſiſtance to be overcome. Of this ſort are the bones of our legs and arms, and the wheels of clocks and watches. See Lever and Balance.

2. In the *wheel and axle*, where the power is applied to the wheel, and the weight drawn up by a rope winding round the axle, the velocity of the power is to the velocity of the weight, as the circumference of the wheel is to the circumference of the axle, and the advantage gained by the machine is in the ſame proportion: for the power and weight balance each other when the power is in proportion to the weight, as the circumference of the axle is to the circumference of the wheel. This machine is the principal part of a common *crane*. See Axis in *Peritrochio*.

3. A *pulley*, that only turns on its axis, and does not riſe with the weight, ſerves only to change the direction of the power; for it gives no mechanical advantage thereto. But when, beſides the upper pullies, which turn round in a fixed frame, or block, there is a block of pullies moving equally faſt with the weight, the velocity of the weight is to the velocity of the power as one is to twice the number of pullies in the moveable block: and the power and weight balance each other when the power is in proportion to the weight, as one is to twice the number of pullies in the moveable block. See Pulley.

4. An *inclined plane* is like one-half of a wedge which has been cut in two equal parts lengthwiſe. A weight raiſed, or a reſiſtance moved, by an inclined plane, moves only through a ſpace equal to the height of that machine, in the time that a power drives it through a ſpace equal to its whole length. Therefore, the velocity of the power is in proportion to the velocity of the weight, as the length of the machine is to its thickneſs or height at the back; and the power and weight balance each other when the power is in proportion to the weight, as the thickneſs of the plane is to its length. All edge tools, which are chamfered (or ground down only on one ſide to the edge) are inclined planes. as far as the chamfer goes from the edge. See *Inclined* Plane.

5. A *wedge*, in the common form, is like two inclined planes, joined together at their baſes; and the thickneſs of theſe planes (oppoſite their ſharp edges) makes the back of the wedge, to which the power of the ſledge or hammer is applied in cleaving of wood.

When two equal reſiſtances act perpendicularly againſt oppoſite ſides of the wedge, and a power acts perpendicularly againſt the back of the wedge, the velocity of the power is in proportion to the velocity of the reſiſtance on either ſide, as the length of the ſide is to half the thickneſs of the back: and the power balances the reſiſtance of the wood, when the power is in proportion to the reſiſtance, as half the thickneſs of the back of the wedge is to the length of either of its ſides, if the ſharp edge goes to the bottom

of the cleft in the wood. But when the wood ſplits before the wedge, as it generally does, the power balances the reſiſtance, when the former is to the latter as half the thickneſs of the wedge (when it is driven quite into the wood) is to the whole length of the cleft below the back of the wedge. See WEDGE.

6. The *ſcrew* may be conſidered as if it were an inclined plane, wrapt round a cylinder. In this machine, the power muſt turn the cylinder quite round, in the time that the weight or reſiſtance (as in a common preſs) moves through a ſpace equal to the diſtance between the threads or ſpirals of the ſcrew. Therefore, the velocity of the power is in proportion to the velocity of the weight or reſiſtance, as the circumference of a circle, deſcribed by the power, is to the diſtance between the ſpirals of the ſcrew; and the power and reſiſtance balance each other, when the former is to the latter as the diſtance between the ſpirals is to the circumference of the circle deſcribed by the power. This machine, beſides the advantage peculiar to itſelf, has generally the benefit of the wheel and axle, on account of the winch or lever by which it is turned. See SCREW.

Of theſe ſix ſimple machines, all the moſt compound engines in the world are made. As the ſcrew includes the inclined plane, and two equally inclined planes make the wedge, we have all the mechanical powers combined together in a common jack, if it be turned by the fly; for then we have alſo the lever, the wheel and axle, and the pullies.

Thus, in a frame A B C D, (*Plate* XXXII. *Mechanics*, *fig*. 5.) faſtened by the nut O upon the ſtand O O, and held together by the pillars V W and B *q*, is adapted firſt the piece E F, whoſe fans or flies may be put in motion by the wind, or drawn by a hair faſtened at F, which repreſents the lever and balance: at right angles to this piece is joined the perpendicular ſpindle G H, having upon it the endleſs ſcrew H, which may be alſo conſidered as a wedge. This endleſs ſcrew or worm takes the ſkew teeth of the wheel K, which is the axis in peritrochio, and, in turning round, winds up the ſtring L M upon its axis, which paſſing round the pullies at M and N, or drawing by a tackle of five, raiſes the weight P. But as the ſcrew has no progreſſive motion on its axis, it cannot here be ſaid to comprehend the inclined plane; therefore, in order to make this machine take in all the mechanical powers, we may add the inclined plane, *r q* Q R, by making it reſt on the ground at Q R, and on the pillar *q* B, at *q r*, and thereby the force of the power drawing at F, will be farther increaſed in the proportion of Q T to T S. The whole force gained by this machine is found by comparing the ſpace gone through by the point F, with the height through which the weight is raiſed, in any determinate number of revolutions of F. An hundred pounds weight at P will be eaſily raiſed by the hair of a man's head drawing at F.

If an engine conſtructed in this manner be uſed for raiſing a weight, by means of a power applied to the fly, the power will balance the weight, if it be in proportion to the weight as the velocity of the weight is to the velocity of the fly. Now, conſidering how faſt the fly moves with reſpect to the motion of the weight, it is evident, that a crane, conſtructed in the manner of a common jack, would be an engine of very great power. But then the time loſt in raiſing the weight would alſo be very great: for, in any machine or engine whatever, the time loſt in working it will be as great as the power gained by it.

If machines or engines could be made without friction, the leaſt degree of power added to that which balances the weight would be ſufficient to raiſe it. In the lever, the friction is next to nothing; in the wheel and axle it is but ſmall; in the pullies it is very conſiderable; and in the inclined plane, wedge, and ſcrew, it is very great. The univerſal law or principle in all mechanical machines or engines, made to gain power, is, that the power gained will be always as great as the velocity of the power exceeds the velocity of the weight or reſiſtance: and, upon this principle, it is eaſy to compute the power, force, or advantage, of any ſimple machine or compound engine whatever.

E gr. If the body A (*Plate* XXXII. *Mechanics*, *fig*. 6.) be triple the body B, and each of them be ſo fixed to the extremities of a lever A B, whoſe fulcrum or fixed point is C, as that the diſtance of B C be triple the diſtance C A; the lever cannot be inclined on either ſide, but the ſpace B E, paſſed over by the leſs body, will be triple the ſpace A D, paſſed over by the great one. So that their motions or moments will be equal, and the two bodies in equilibrio.

Hence that noble challenge of Archimedes, *datis viribus, datum pondus movere;* for as the diſtance C B may be increaſed infinitely, the power or moment of A may be increaſed infinitely. So that the whole of mechanics is reduced to the following problem.

Any body, as A, *with its velocity* C, *and alſo any other body, as* B, *being given; to find the velocity neceſſary to make the moment or quantity of motion, in* B, *equal to the moment of* A, *the given body.* Here, ſince the moment of any body is equal to the rectangle under the velocity, and the quantity of matter; as B : A :: C : to a fourth term, which will be *c*, the celerity proper to B, to make its moment equal to that of A. Wherefore in any machine or engine, if the velocity of the power be made to the velocity of the weight, reciprocally as the weight is to the power, ſuch power will always ſuſtain, or, if the power be a little increaſed, it will move the weight.

Let, for inſtance, A B be a lever, whoſe fulcrum is at C, and let it be moved into the poſition *a* C *b*. Here, the velocity of any point in the lever is as the diſtance from the centre. For let the point A deſcribe the arc A *a*, and the point B the arc B *b*; then theſe arcs will be the ſpaces deſcribed by the two motions: but ſince the motions are both made in the ſame time, the ſpaces will be as the velocities. But it is plain, the arcs A *a* and B *b* will be to one another as the radii A C and C B, becauſe the ſectors A C *a* and B C *b* are ſimilar: wherefore the velocities of the points A and B are as their diſtances from the centre C.

Now if any powers be applied to the ends of the lever A and B, in order to raiſe its arms up and down; their force will be expounded by the perpendiculars S *a* and *b* N; which, being as the right ſines of the former arcs, *a* A and B *b*, will be to one another alſo as the radii A C and C B; wherefore the velocities of the powers are alſo as their diſtances from the centre. And ſince the moment of any body is as its weight, or gravitating force, and its velocity, conjunctly; if different powers of weights be applied to the lever, their moments will always be as the weights and the diſtances from the centre conjunctly. Wherefore, if to the ſame lever there be two powers or weights applied reciprocally proportional to their diſtances from the centre, their moments will be equal; and if they act contrarily, as in the caſe of a ſteel-yard, the lever will remain in an horizontal poſition, or the balance will be in equilibrio. And thus it is eaſy to conceive how the weight of one pound may be made to equibalance a thouſand, &c.

Hence alſo it is plain, that the force of the power is not at all increaſed by engines; only the velocity of the weight, in either lifting or drawing, is ſo diminiſhed by the application of the inſtrument, as that the moment of the weight is not greater than the force of the power. Thus, for inſtance,

if any force can raise a pound weight with a given velocity, it is impossible by any engine to effect, that the same power shall raise two pound weight with the same velocity: but by an engine it may be made to raise two pound weight, with half the velocity; or 1000 times the weight with $\frac{1}{1000}$ of the former velocity.

We shall here introduce into one view, an account of the principal methods that have occurred to us of explaining and demonstrating the fundamental property of the several mechanical powers. It has been already observed, that, with regard to the lever, when any two forces act against each other on its arms, they will continue in equilibrio, if their quantities are inversely as the distance between the points to which they are applied, and the point or fulcrum round which the lever turns. The demonstration commonly ascribed to Archimedes is founded upon this principle, that when any cylindric or prismatic body is applied upon a lever, it has the same effect as if its whole weight was united and applied at the middle point of its axis. Let A B, *Plate* XXXII. *Mechanics*, *fig.* 7, be a cylinder, of an uniform texture, C its middle point; and it is manifest, that if the point C be supported, the equal halves of the cylinder, C A and C B, will balance each other about the point C, and the body will remain in equilibrio. Let the cylinder A B be distinguished into any unequal parts, A D and D B; bisect A D in E, and D B in F; then a power applied at E, equal to the weight of the part A D, with a contrary direction, will sustain it; and a power applied at F, equal to the weight of the part D B, with a contrary direction, will sustain that part; so that these two powers acting at E and F, respectively equal to the weights of A D and D B, have precisely the same effect as a prop at C, sustaining the whole cylinder A B, and may be considered as in equilibrio with a power, acting at C, equal to the whole weight of the cylinder. But the distance $CE = CA - AE = \frac{1}{2}AB - \frac{1}{2}AD = \frac{1}{2}DB$; and, in like manner, the distance $CF = CB - BF = \frac{1}{2}AB - \frac{1}{2}DB = \frac{1}{2}AD$; consequently C E is to C F as D B to A D; that is, as the power applied at F to the power applied at E, these being in equilibrio with the weight of the whole cylinder applied at C. From which it appears, that powers applied at E and F, which are to each other in the proportion of C F to C E, sustain one another about the centre C.

It has been objected by M. Huygens and others, to this demonstration of Archimedes, that when the whole cylinder is distinguished into two segments, part of the weight of the greater segments acts on the same side of the fulcrum with the lesser segment; and, therefore, when the whole weight of the greater segment is contracted into its middle point on one side of the fulcrum, and acts altogether against the lesser segment, it requires some proof to shew, that this contracted weight will be balanced by the weight of the lesser segment. M. Huygens proposed a method of his own, depending on a postulatum assumed in common with Archimedes, and needing demonstration, *viz.* that when equal bodies are placed on the arms of a lever, the one which is farthest from the fulcrum will prevail and raise the other up.

Sir Isaac Newton demonstrates the fundamental proposition concerning the lever, from the resolution of motion: let C, *fig.* 8, be the centre of motion in the lever K L; let A and B be any two powers applied to it at K and L, acting in the directions K A and L B. From the centre of motion, C, let C M and C N be perpendicular to those directions in M and N; suppose C M to be less than C N, and from the centre C, at the distance C N, describe the circle N H D, meeting K A in D. Let the power A be represented by D A, and let it be resolved into the power D G acting in the direction C D, and the power D F perpendicular to C D, by completing the parallelogram A F D G. The power D G, acting in the direction C D from the centre of the circle, or wheel, D H N, towards its circumference has no effect in turning it round the centre, from D toward H, and tends only to carry it off from that centre. It is the part D F only that endeavours to move the wheel from D towards H and N, and is totally employed in this effort. The power B may be conceived to be applied at N as well as at L, and to be wholly employed in endeavouring to turn the wheel the contrary way, from N towards H and D. If, therefore, the power B be equal to that part of A which is represented by D F, these efforts, being equal and opposite, must destroy each other's effect; that is, when the power B is to the power A, as D F to D A, or (because of the similarity of the triangles, A F D, D M C) as C M to C D or as C M to C N, then the powers must be in equilibrio; and those powers always sustain each other that are in the inverse proportion of the distances of their directions from the centre of motion; or when the product of the one power multiplied by the distance of its direction from the centre, is equal to the product of the power on the other side multiplied by the like distance from it.

Mr. Maclaurin proposes a new method of demonstrating the law of equilibrium in the lever, which seems, he says, to be founded on the plainest and most evident principles: these principles are the following, *viz.* that if equal powers act at equal distances on different sides of the fulcrum or centre of motion, with directions opposite and parallel to each other, they will have the same effect: and that, if gravity be supposed to act in parallel lines, and the fulcrum be between the bodies, whose powers are estimated, it must bear the sum of their weights; because the lever being loaded with those weights, it must give way, if the fulcrum does not sustain their sum: but if the powers are on the same side of the fulcrum, in which case one of them must pull upwards whilst the other pulls downwards, that there may be an equilibrium, it is then only loaded with the difference of the powers.

Supposing, therefore, first, two equal powers, A and B, *fig.* 9, acting in the directions A F, B H, to carry a body C, upon the lever A B, placed at C at equal distances from them; it is evident that, in this case, each of the powers A and B sustains one-half of the weight C, by dividing it equally between them. Imagine now that the power A is taken away, and that, instead of resting upon it, the end A of the lever rests upon a prop at A; it is manifest that the power B, and the prop at A sustain, as before, each one-half of the weight C; the prop now acting, in every respect, as the power at A before; and, the equilibrium continuing, it appears that, in this case, a power B equal to one-half of the weight C sustains and balances it, when the distance of C from the prop A is one-half of the distance of B from the same; that is, when B is to C, as C A to B A, or $B \times BA = C \times CA$. From this simple instance we see, that powers act upon a lever not by their absolute force only, but that their effect necessarily depends upon the distance of the point where they act from the prop, or centre of motion; and particularly, that a power balances a double power which acts at half its distance from the prop, on the same side of it, with an opposite direction.

The case when the two powers act on the different sides of the prop, follows from this, by the principles already laid down. For let B H and C G (*fig.* 10.) represent the directions and forces with which the powers B and C act upon the lever; upon B A produced take A E equal to A C, or $\frac{1}{2}$ A B, and in place of the power C G substitute

an equal power E K at E, with an oppofite direction; and, by the firft of thofe principles, this power E K will have the fame effect as C G, only the prop or centre of motion A will now fuftain the fum of the forces E K and B H, by the fecond of thofe principles. But the equilibrium between the powers B H and E K will continue as it was before, between B H and C G; fo that the powers B H and E K will be in equilibrio, when the power B H is one-half of E K, and the diftance of E K from the prop A is one-half of the diftance of B H from the fame; that is, when the power at B is to the power at E, as A E to A B, or $B \times BA = E \times EA$. In this cafe, the prop A being loaded with both the powers B and E, which act with the fame direction, its re-action muft be equal to their fum, $EK + BH = 3\ BH$, and muft be in the oppofite direction A F. In place of this re-action, let us now (*fig.* 11.) fubftitute a power A F at A, equal to thrice B H; and in place of the power E K, let us fubftitute a prop at E, fuftaining that end of the lever B E; and fince the equilibrium continues as before, it follows that the prop or centre of motion, being at E, the power B H fuftains the power A F, which is triple of B H, when the diftance of B H from the prop E is triple of the diftance of the power A F from the fame, that is, when $BH \times BE = AF \times AE$.

If we fuppofe the power E K to remain (*fig.* 12.) but the end B of the lever E B to reft upon a prop, then the powers A F and E K will fuftain and balance each other, the prop at B now coming in place of the power B H; in which $AF = 3\ BH$, and $EK = 2\ BH$; fo that A F is to E K as 3 to 2; and the diftances E B and A B being in the fame proportion, it appears that when two powers in the proportion of three to two act upon a lever on the fame fide of the prop, or centre of motion, with oppofite directions, at diftances in the proportion of two to three, they then fuftain each other. We have demonftrated therefore, that when the powers are in the proportion either of two to one, or of three to one, or of three to two, and the diftances of their application from the centre of motion are in the inverfe proportion, then thofe powers balance each other, or are in equilibrio.

Upon B E produced (*fig.* 13.) take $EL = EA$; and in place of the power A F fubftitute a power $LM = AF$, but with a contrary direction; this power L M will have the fame effect to turn the lever round the centre of motion E as A F had; confequently it will be in equilibrio with the power B H, as A F was. Therefore, when two powers L M and B H, in the proportion of three to one, act upon a lever with the fame direction, they are in equilibrio, if their diftances from the centre of motion L E and E B be in the ratio of one to three: that is, when $LM \times LE = BH \times BE$. In this cafe, the powers L M and B H acting with the fame direction, the prop E muft fuftain their fum $LM + BH = 4\ BH$, by the fecond principle above premifed. Therefore a power at L, as 3, and a power acting at B with the fame direction, as 1, are fuftained by a power acting at E, with a contrary direction, as 4. From which it follows, by fubftituting in the place of the power L M a prop at L, that a power at B, as 1, fuftains a power at E, as 4, acting with a contrary direction, when B L is to E L as 4 to 1; that is, when the powers are inverfely as their diftances from the prop, or centre of motion. By fubftituting the prop at B in the place of the power B H, it appears that a power L M at L, as 3, fuftains a power acting with an oppofite direction at E, as 4, when their diftances L B and E B, from the prop B, are to each other as 4 to 3, or when $LM \times LB = EK \times EB$. By taking upon L B produced $Be = BE$ (*fig.* 14.), and in place of the power at E, fubftituting an equal power at *e* with a contrary direction, it appears, that a power at L, as 3, fuftains a power acting at *e*, with the fame direction, as 4, when the diftance L B is to the diftance *e* B, as 4 to 3. In this cafe, the prop at B fuftains the fum of the powers acting at L and *e*, that is, a power equal to feven times B H. From which it follows, by fubftituting a prop at L or *e*, in place of the powers that act there, that a power at *e*, as 4, fuftains a power at B, as 7, about the centre of motion L, when their diftances from it, *e* L, B L, are to each other as 7 to 4: and that a power at L, as 3, fuftains the power at B, as 7, about the centre of motion *e*, when their diftances from it, L *e* and B *e*, are to each other as 7 to 3.

By proceeding in this manner it appears, that when the powers are to each other as number to number, and when their diftances from the centre of motion are in the inverfe ratio of the fame numbers, then the powers fuftain each other, or are in equilibrio. From which it is eafy to fhew, in general, that when the powers are to each other in any ratio, though incommenfurable, and the diftances of their application from the centre of motion in the fame inverfe ratio, then they are in equilibrio; becaufe the ratio of incommenfurable quantities may be always limited to any degree of exactnefs at pleafure, between a greater and a leffer ratio of number to number. To Mr. Maclaurin's demonftration it has been objected, that it cannot be applied when the arms of the lever are incommenfurable, and as it cannot conclude generally, it muft, therefore, be imperfect.

Dr. Hamilton, having obferved that thefe feveral methods of demonftrating the fundamental property of the lever are liable to objections, propofes a new proof, depending on the following poftulatum, *viz.* if a force be uniformly diffufed over a right line, fo that an equal part of the force acts upon every point of the line, and if the whole force acts according to one and the fame plane, this force will be fuftained, and the line kept in equilibrio, by a fingle force applied to the middle point of the line equal to the diffufed force, and acting in a contrary direction. He alfo premifes this lemma: if a right line be divided into two fegments, the diftances between the middle of the whole line and the middle points of the fegments, will be inverfely as the fegments. This is felf-evident when the fegments are equal; and, when they are unequal, fince half of the whole line is equal to half of the greater and half of the leffer fegment, it is plain that the diftance between the middle of the whole line and the middle of one fegment, muft be equal to half of the other fegment, fo that thefe diftances muft be to each other inverfely as the fegments.

Let the line G H, then, *fig.* 15, whofe middle point is D, be divided into the unequal fegments G L and L H, whofe middle points are C and F, and let two forces or weights, A and B, which are to each other as the fegments G D and L H, be applied to their middle points C and F, and let them act perpendicularly on the line G H: then, (by the lemma) the weights A and B will be to each other inverfely as C D and F D (the diftances of the points C and F, to which they are applied, from the middle of the whole line); if then a third force or weight E, equal to the fum of the forces A and B, be applied to the point D, and acts on the line in an oppofite direction; I fay thefe three forces will fuftain each other, and keep the line in equilibrio. For let us fuppofe the force E to be removed, and inftead of it another force, equal alfo to the fum of A and B, to be uniformly diffufed over the whole line G H, and to act directly againft the forces A and B, then the part of this force which acts on the fegment G L, will be equal to the force A, and therefore will be fuftained by it (poftu-

latum); and the other part, which is diffused over the segment L H, will be equal to and sustained by the force B, so that the forces A and B will sustain this diffused force and keep the line in equilibrio. Let now two other forces act also on this line in opposite directions, one of them the force E acting on the point D, as it was first supposed to do, and the other an uniformly diffused force equal to E (and consequently equal to the other diffused force), then these two additional forces will also balance each other, and therefore the equilibrium will still remain. So that the two forces A and B, and a diffused force acting on one side of the line sustains the force E, and a diffused force acting on the other side: but it is manifest, that in this equilibrium, the two diffused forces acting on opposite sides are perfectly equivalent, and therefore if they are taken away from both sides, the equilibrium must still remain. Hence it appears that the three weights or forces A, B, and E, any two of which are, (by the construction) to each other inversely as their distances from the third, will sustain each other and keep the line on which they act in equilibrio; which is the first and most simple case of the property of the lever; for here the directions of the weights are supposed to be perpendicular to the line on which they act, and it is evident that, if one of the points C, D, or F be fixed or considered as a fulcrum, the weights acting on the other two points will continue to support each other. The second case of the property of the lever is easily deduced from the first; for when two weights act on the arms of a lever in oblique directions, and are to each other inversely as the perpendicular distances of the lines of direction from the centre of motion, then by the resolution of forces, it is easily proved that the parts of those forces which act perpendicularly on the arms of the lever, and which only are exerted to turn the lever, are to each other inversely as the lengths of those arms; and therefore by the first case they must balance each other.

From what has been above demonstrated, it appears, that the powers with which any two forces move or endeavour to move the arms of a lever, are as the rectangles, under lines proportional to the forces, and the perpendicular distances of their lines of direction from the fulcrum; and also that when two bodies acting on the arms of a lever sustain each other, if one of them be removed farther from the fulcrum, it will preponderate; but if it be brought nearer to the fulcrum, the other weight will prevail: because the product to which its force is proportional will be increased in the first case, and diminished in the second.

When a weight is to be raised by means of an axle and wheel, it is fastened to a chord that goes round the axle, and the power, which is to raise it, is hung to a chord that goes round the wheel. If then the power be to the weight as the radius of the axle to the radius of the wheel, it will just support that weight; as will easily appear from what was proved of the lever. For the axle and wheel may be considered as a lever, whose fulcrum is a line passing through the centre of the wheel and middle of the axle, and whose long and short arms are the radii of the wheel and axle which are parallel to the horizon, and from whose extremities the chords hang perpendicularly. And thus an axle and wheel may be looked upon as a kind of perpetual lever, on whose arms the power and weight always act perpendicularly, though the lever turns round its fulcrum. And in like manner, when wheels and axles move each other by means of teeth on their peripheries, such a machine is really a perpetual compound lever; and, by considering it as such, we may compute the proportion of any power to the weight it is able to sustain by the help of such an engine. And since the radii of two contiguous wheels, whose teeth are applied to each other, are as the number of teeth in each, or inversely as the number of revolutions, which they make in the same time: we may, in the computation, instead of the ratio of these radii, put the ratio of the number of teeth on each wheel; or the inverse ratio of the number of revolutions they make in the same time.

The most natural method of explaining the effects of the pulley, that is, of computing the proportion of any power to the weight it can sustain by means of any system of pullies, is, by considering that every moveable pulley hangs by two ropes equally stretched, which must bear equal parts of the weight: and, therefore, when one and the same rope goes round several fixed and moveable pullies, since all its parts on each side of the pullies are equally stretched, the whole weight must be divided equally amongst all the ropes by which the moveable pullies hang. And consequently if the power which acts on one rope be equal to the weight divided by the number of ropes, or double the number of moveable pullies, that power must sustain the weight.

The several cases in which the wedge is applied may be comprehended in one general proposition: let the equicrural triangle A B C (*fig.* 16.) represent a wedge, the lines A B and C B will be the sides of the wedge, A C its base, or back, and its height will be the line P B bisecting the base A C, and also the vertical angle A B C.

When any two resisting forces act on the sides of a wedge, in directions which make equal angles with the sides, (as they are always supposed to do,) a power acting perpendicularly at P on the base of the wedge will keep the resisting forces in equilibrio, when it is to the sum of these forces, as the sine of half the vertical angle of the wedge, to the sine of the angle which the directions of the forces contain with the sides of the wedge.

For let E and F be two bodies acting on the sides of the wedge, and let them be first supposed to act in the directions E P and F P perpendicular to the sides; then since the power P acts perpendicularly on the base A C, if these three forces keep the wedge in equilibrio, they will be to each other, as the sides of a triangle to which their directions are parallel, or (which is the same thing) as the sides of the triangle A B C, to which their directions are perpendicular. Therefore, the power P is to the sum of the resisting forces which it sustains as A C, the base of the wedge, to the sum of the sides, or as P A, half the base, to A B, one of the sides; but P A is to A B as the sine of P B A, half the vertical angle of the wedge, to the radius which is the sine of a right angle, and the directions of the resisting forces are supposed in this case to contain a right angle with the sides of the wedge.

Let now the resisting bodies E and F be supposed to act on the wedge in directions parallel to the lines D P and O P, which make oblique angles with its sides, draw E G and F K perpendicular to those lines. From what has been proved, it appears that the power P is to the force with which it is able, by means of the wedge, to protrude the resisting bodies in the directions P E and P F, as the sine of half the vertical angle to the radius; let this protruding force be expressed by the line P E, and let it be resolved into two forces expressed by the lines P G and G E, the former of these only will act in opposition to the resisting bodies, therefore the whole protruding force of the power is to the force with which it acts against the resisting bodies E and F in the directions P D and P O as P E to P G, or (because the triangles E P G and D P E are similar) as P D to P E, that is, as the radius to the sine of the angle P D E; compounding, therefore, the ratio of the sine of half the vertical angle to the radius, with the ratio of the radius to the sine of the angle P D E,

the power P, when the wedge is kept in equilibrio, will be to the force with which it protrudes the resisting bodies in directions opposite to those in which they act, as the sine of half the vertical angle to the sine of the angle P D E or P O F, which the directions of the resisting forces contain with the sides of the wedge.

Hence, when the directions in which resisting bodies act on a wedge are given, we may easily find two lines that will express the proportion between the resistance and the power which sustains it by means of the wedge. For from P, the middle point of the wedge, draw the line P D meeting one of the sides, and parallel to the direction in which the resisting force acts on that side, then the power will be to the resistance as P D to P B the height of the wedge. For P D and P B are to each other as the sines of the opposite angles, in the triangle P B D, that is, as the sines of half the vertical angle, and the angle which the direction of the resisting force contains with the side of the wedge.

From what has been demonstrated we may deduce the proportion of the power to the resistance it is able to sustain, in all the cases in which the wedge is applied.

First, when, in cleaving timber, the wedge fills the cleft, then the resistance of the timber acts perpendicularly on the sides of the wedge; therefore, in this case, when the power which drives the wedge is to the cohesive force of the timber as half the base to one side of the wedge, the power and resistance will be in equilibrio.

Secondly, when the wedge does not exactly fill the cleft, which generally happens because the wood splits to some distance before the wedge: let E L F represent a cleft, into which the wedge A B C is partly driven; as the resisting force of the timber must act on the wedge in directions perpendicular to the sides of the cleft, draw the line P D in a direction perpendicular to E L, the side of the cleft, and meeting the side of the wedge in D; then the power driving the wedge, and the resistance of the timber, when they balance, will be to each other as the line P D to P B, the height of the wedge.

Thirdly, when a wedge is employed to separate two bodies that lie together on a horizontal plane, for instance two blocks of stone; as these bodies must recede from each other in horizontal directions, their resistance must act on the wedge in lines parallel to its base C A; therefore, the power which drives the wedge will balance the resistance, when they are to each other as P A, half the breadth of the wedge, to P B its height; and then any additional force, sufficient to overcome the resistance arising from the friction of the bodies on the horizontal plane, will separate them from each other.

With respect to the inclined plane: let the line A B, (*fig.* 17.) represent the length of an inclined plane, A D its height, and the line B D we may call its base. Let the circular body G E F be supposed to rest on the inclined plane, and to be kept from falling down it by a string C S tied to its centre C. Then the force with which this body stretches the string will be to its whole weight as the sine of A B D, the angle of elevation, to the sine of the angle which the string contains with a line perpendicular to A B, the length of the plane. For let the radius C E be drawn perpendicular to the horizon, and C F perpendicular to A B, and from E draw E O parallel to the string, and meeting C F in O: then, as the body continues at rest, and is urged by three forces, to wit, by its weight in the direction C E, by the re-action of the plane in the direction F C, and by the re-action of the string in the direction E O; the re-action of the string, or the force by which it is stretched, is to the weight of the body as E O to C E; that is, as the sine of (the angle E C O, which is equal to) A B D, the angle of elevation, to the sine of the angle E O C, equal to S C O, the angle which the string contains, with the line C F perpendicular to A B, the length of the plane.

When, therefore, the string is parallel to the length of the plane, the force with which it is stretched, or with which the body tends down the inclined plane, is to its whole weight, as the sine of the angle of elevation to the radius, or as the height of the plane to the length. And in the same manner it may be shewn, that when the string is parallel to B D, the base of the plain, the force with which it is stretched is to the weight of the body as A D to B D, that is, as the height of the plane to its base. If we suppose the string, which supports the body G E F, to be fastened at S, and that a force by acting on the line A D, the height of the plane, in a direction parallel to the base B D, drives the inclined plane under the body, and by that means makes it rise to a direction parallel to A D: then, from what was proved in the third case of the wedge, it will appear, that this force must be to the weight of the body as A D to B D, or rather in a proportion somewhat greater; if it makes the plane move on and the body rise.

From this last observation we may clearly shew the nature and force of the screw; a machine of great efficacy in raising weights, or in pressing bodies closely together. For if the triangle A B D be turned round a cylinder whose periphery is equal to B D, then the length of the inclined plane B A will rise round the cylinder in a spiral manner, and form what is called the thread of the screw, and we may suppose it continued in the same manner round the cylinder, from one end to the other; and A D, the height of the inclined plane, will be every where the distance between two contiguous threads of this screw, which is called a convex screw. And a concave screw may be formed to fit this exactly, if an inclined plane every way like the former be turned round the inside of a hollow cylinder, whose periphery is somewhat larger than that of the other. Let us now suppose the concave screw to be fixed, and the convex one to be fitted into it, and a weight to be laid on the top of the convex screw: then, if a power be applied to the periphery of this convex screw to turn it round, at every revolution the weight will be raised up through a space equal to the distance between the two contiguous threads, that is, to the line A D, the height of the inclined plane B A; therefore, since this power applied to the periphery acts in a direction parallel to B D, it must be to the weight it raises as A D to B D, or as the distance between two contiguous threads, to the periphery of the convex screw.

The distance between two contiguous threads is to be measured by a line parallel to the axle; if we now suppose that a handspike or handle is inserted into the bottom of the convex screw, and that the power which turns the screw is applied to the extremity of this handle, which is generally the case; then as the power is removed farther from the axis of motion, its force will be so much increased, and therefore so much may the power itself be diminished. So that the power which, acting on the end of a handle, sustains a weight by means of a screw, will be to that weight, as the distance between two contiguous threads of the screw, to the periphery described by the end of the handle. In this case we may consider the machine as composed of a screw and a lever, or, as sir Isaac Newton expresseth it, *Cuneus a vecte impulsus*.

Professor Vince, premising that Dr. Hamilton's demonstration depends upon this proposition, that when a body is at rest, and acted upon by three forces, they will be as the three sides of a triangle parallel to the directions of the

forces, allows this principle to be true, when the three forces act at any point of a body; but, considering the lever as the body, the three forces act at different points, and therefore the principle, as applied by the author, is certainly not applicable. If in this demonstration we suppose a plane body, in which the three forces act, instead of simply a lever, then the three forces being actually directed to the same point of the body, the body would be at rest. But in reasoning from this to the case of the lever, the same difficulties would arise, as in the proof of sir I. Newton. But admitting that all other objections could be removed, the demonstration fails when any two of the forces are parallel. Another demonstration is founded upon this principle, that if two non-elastic bodies meet with equal quantities of motion, they will, after impact, continue at rest; and hence it is concluded, that if a lever which is in equilibrio be put in motion, the motions of the two bodies must be equal; and therefore the pressures of these bodies upon the lever at rest, to put it in motion, must be as their motions. Now in the first place, this is comparing the effects of pressure and motion, the relation of the measures of which, or whether they admit of any relation, we are totally unacquainted with. Moreover, they act under very different circumstances; for in the former case, the bodies acted immediately on each other, and in the latter, they act by means of a lever, the properties of which we are supposed to be ignorant of. When forces act on a body, considered as a point, or directly against the same point of any body, we only estimate the effect of these forces to move the body out of its place, and no rotatory motion is either generated, or any causes to produce it, considered in the investigation. When we, therefore, apply the same proposition to investigate the effect of forces to generate a rotatory motion, we manifestly apply it to a case which is not contained in it, nor to which there is a single principle in the proposition applicable. The demonstration given by Mr. Landen, in his Memoirs, is founded upon self-evident principles, nor does our author see any objections to his reasoning upon them. But as his investigation consists of several cases, and is besides very long and tedious, something more simple is still much to be wished for, proper to be introduced in an elementary treatise of mechanics, so as not to perplex the young student either by the length of the demonstration, or want of evidence in its principles. What the ingenious Professor proposes to offer will, he hopes, render the whole business not only very simple, but also perfectly satisfactory.

The demonstration given by Archimedes would be very satisfactory and elegant, provided the principle on which it is founded could be clearly proved; *viz. that two equal powers at the extremities, or their sum at the middle of a lever, would have equal effects to move it about any point.* Now, that the effects will be the same, so far as respects any *progressive* motion being communicated to the lever when at liberty to move freely, is sufficiently clear; but there is no evidence whatever that the effects will be the same to give the lever a *rotatory* motion about any point, because a very different motion is then produced, and we are supposed to know nothing about the efficacy of a force at different distances from the fulcrum to produce such a motion. Besides, the two motions are not only different, but the *same* forces are known to produce *different* effects in the two cases; for in the former case the two *equal* powers at the extremities of the arms produce *equal* effects in generating a *progressive* motion; but in the latter case they do *not* produce *equal* effects in generating a *rotatory* motion. We cannot therefore reason from one to the other. The principle, however, may be thus proved.

Let A, C, (*fig.* 18.) be two equal bodies placed on a straight lever, A P, moveable about P; bisect A C in B, produce P A to Q, and take B Q = B P, and suppose the end Q to be sustained by a prop. Then as A and C are similarly situated in respect to each end of the lever, that is, A P = C Q, and A Q = C P, the prop and fulcrum must bear equal parts of the whole weight; and therefore the prop at Q will be pressed with a weight equal to A. Now take away the weights A and C, and put a weight at B equal to their sum; and then the weight at B being equally distant from Q and P, the prop and fulcrum must sustain equal parts of the whole weight, and therefore the prop will now also sustain a weight equal to A. Hence if the prop Q be taken away, the moving force to turn the lever about P in both cases must evidently be the same; therefore the effects of A and C upon the lever to turn it about any point are the same as when they are both placed in the middle point between them. And the same is manifestly true if A and C be placed without the fulcrum and prop. If, therefore, A C be a cylindrical lever of uniform density, its effect to turn itself about any point will be the same as if the whole were collected into the middle point B; which follows from what has been already proved, by conceiving the whole cylinder to be divided into an infinite number of laminæ perpendicular to its axis, of equal thicknesses.

The principle, therefore, assumed by Archimedes is thus established upon the most self-evident principle, that is, that *equal* bodies at *equal* distances must produce *equal* effects; which is manifest from this consideration, that when *all* the circumstances in the cause are equal, the effects must be equal. Thus the whole demonstration of Archimedes is rendered perfectly complete, and at the same time it is very short and simple. The other part of the demonstration we shall here insert, for the use of those who may not be acquainted with it.

Let X Y (*fig.* 19.) be a cylinder, which bisect in A, on which point it would manifestly rest. Take any point Z, and bisect Z X in B, and Z Y in C; then, from what has been proved, the effects of the two parts Z X, Z Y to turn the lever about A is the same as if the weight of each part were collected into B and C respectively, which weights are manifestly as Z X, Z Y, and which therefore conceive to be placed at B and C. Now $AB = AX - XB = \frac{1}{2}XY - \frac{1}{2}XZ = \frac{1}{2}YZ$; and $AC = AY - YC = \frac{1}{2}XY - \frac{1}{2}ZY = \frac{1}{2}XZ$; consequently $AB : AC :: \frac{1}{2}YZ : \frac{1}{2}XZ :: YZ : XZ ::$ the weight at C : the weight at B.

The property of the straight lever being thus established, every thing relative to the bent lever immediately follows. See Maclaurin's Account of sir Isaac Newton's Phil. Disc. book ii. chap. 3. Hamilton's Phil. Ess. ess. 1. or Phil. Trans. liii. p. 116. Phil. Trans. vol. lxxxiv. art. v. p. 33, &c.

MECHANICS.

ACCELERATION.

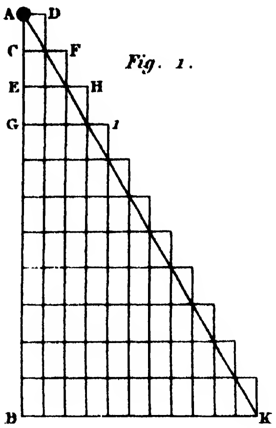


Fig. 1.

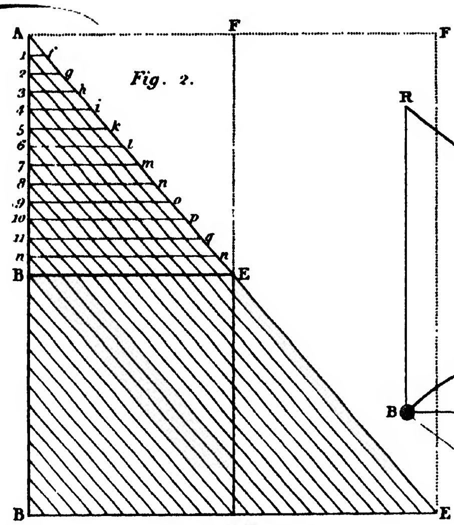


Fig. 2.

ANGLE of Elevation.

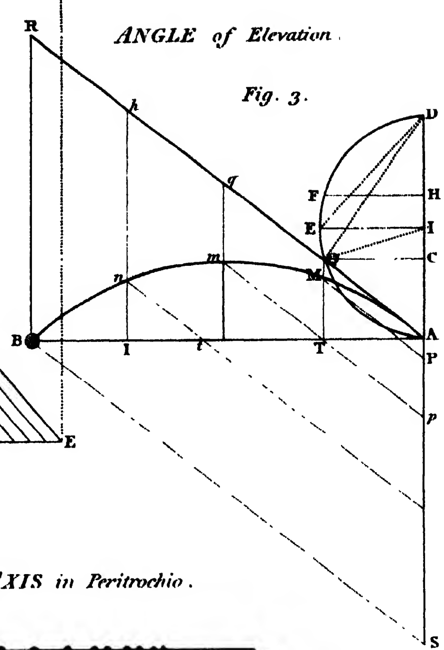
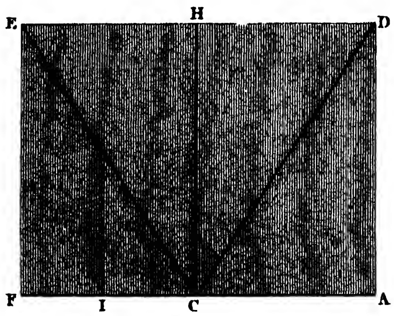


Fig. 3.

Fig. 4.



AXIS in Peritrochio.

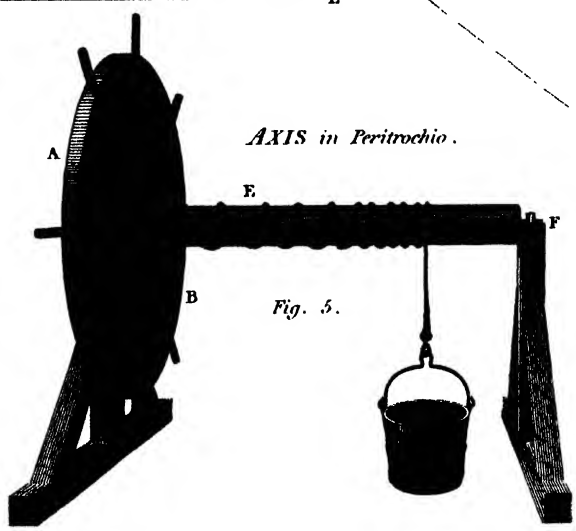


Fig. 5.

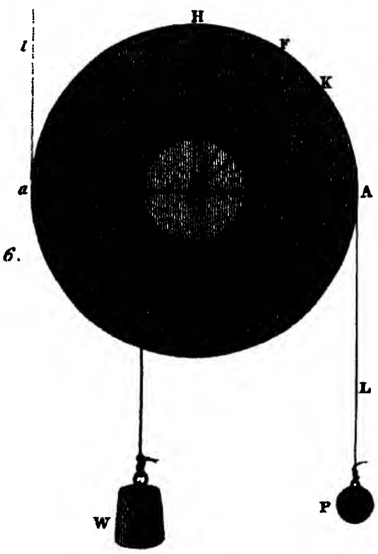


Fig. 6.

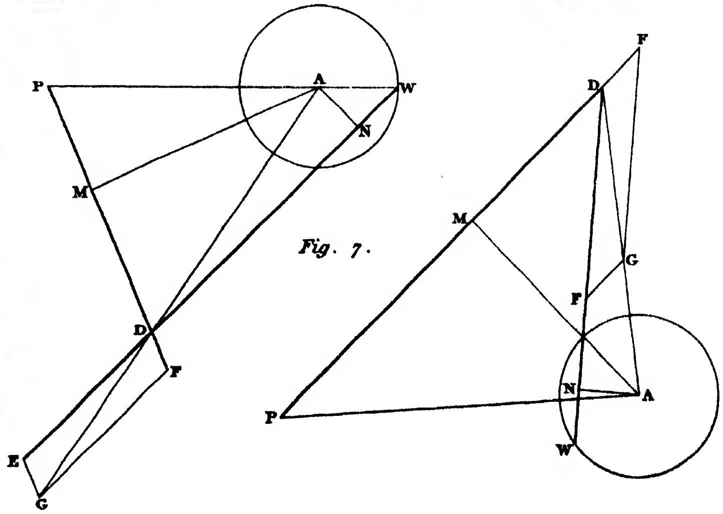


Fig. 7.

Published as the Act directs, April 1, 1807; by Longman, Hurst, Rees & Orme, Paternoster Row.

Engraved by Wilson Lon

Fig. 8.

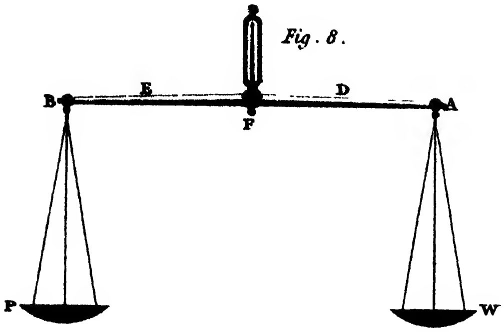


Fig. 9.

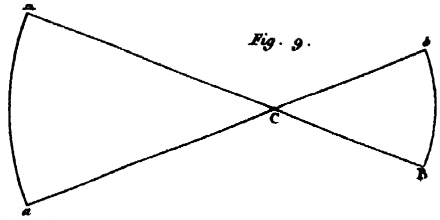


Fig. 10.

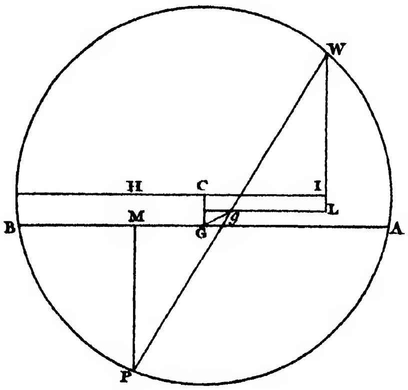


Fig. 11.

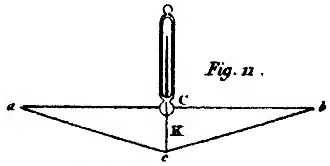


Fig. 12.

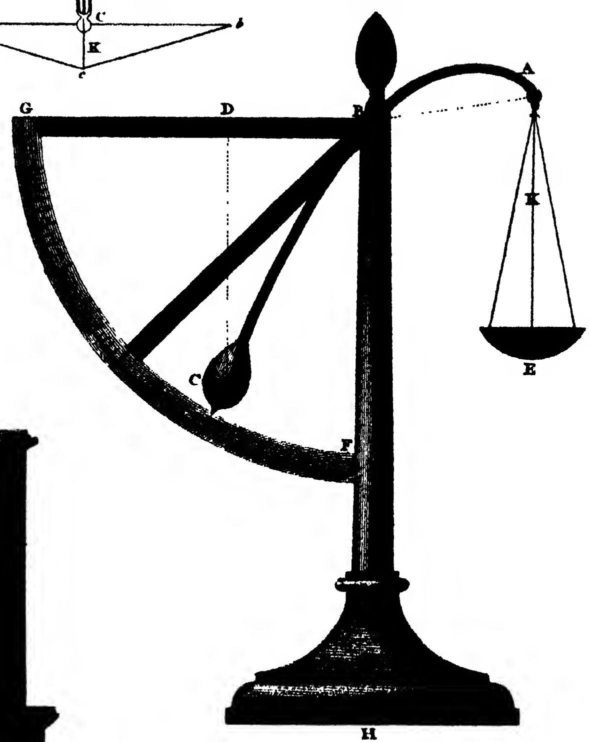


Fig. 13.

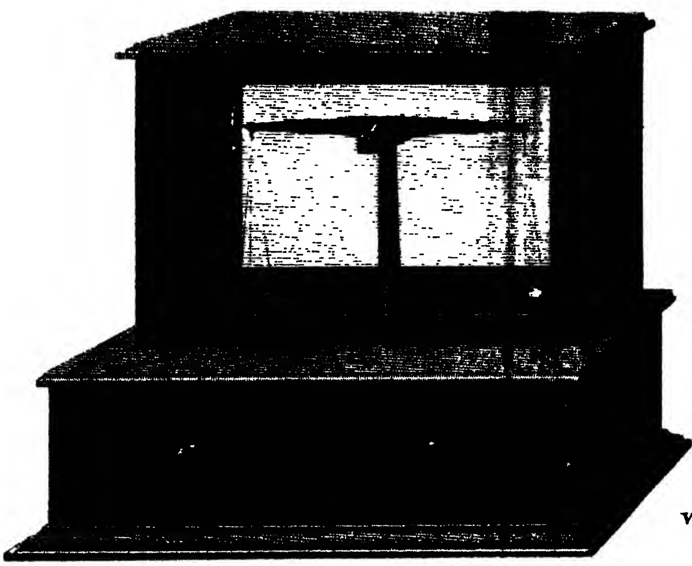
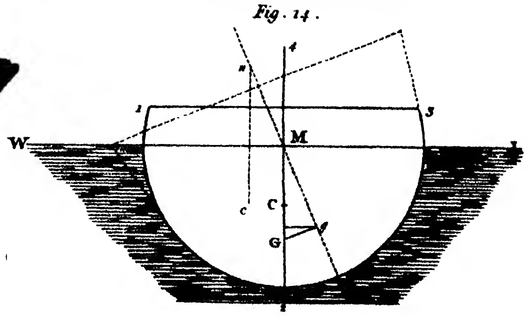


Fig. 14.



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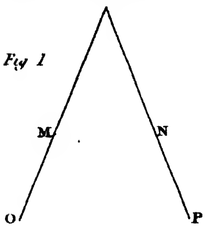
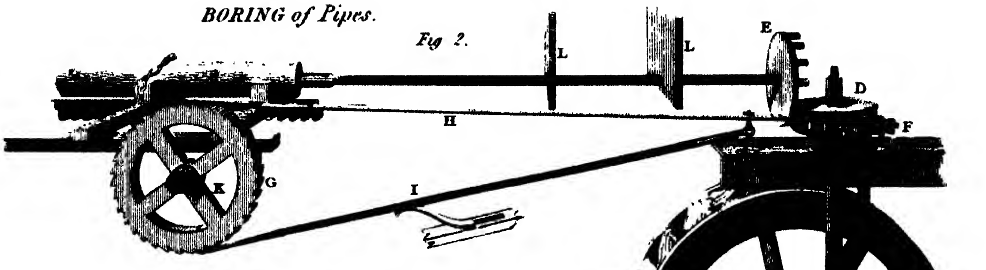
ANGULAR MOTION.

Fig 1



BORING of Pipes.

Fig 2.



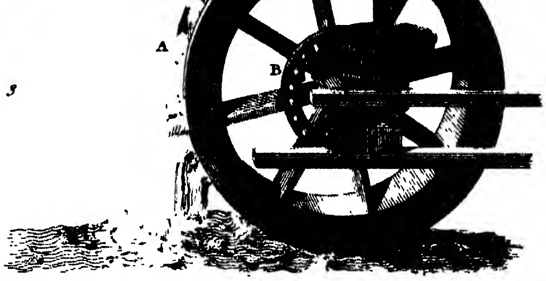


Fig 4

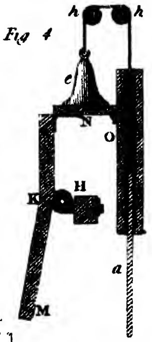
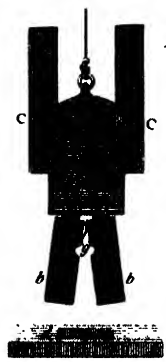
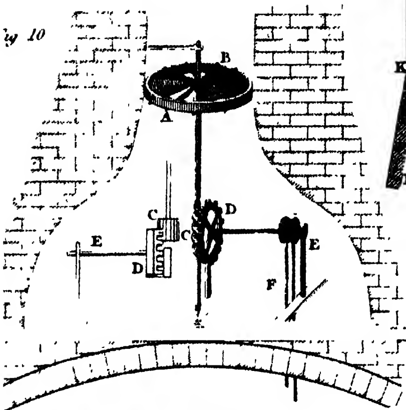


Fig 3



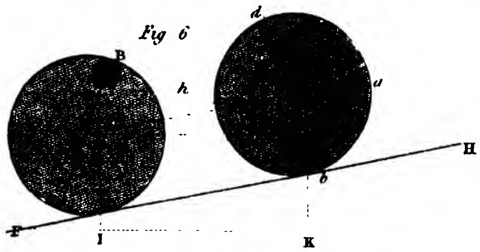
Smoke JACK

Fig 10



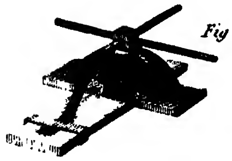
Double CYLINDER

Fig 6



CRAB.

Fig 5



JACK

Fig 9.

Fig. 8

L

Fig 12

LEVER

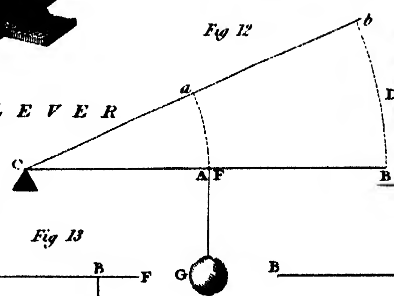


Fig 7

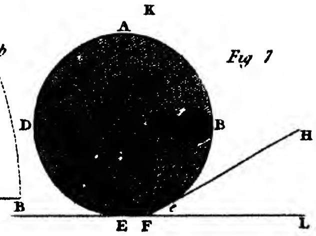


Fig 13

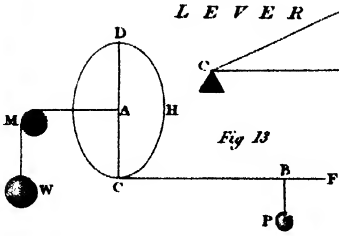
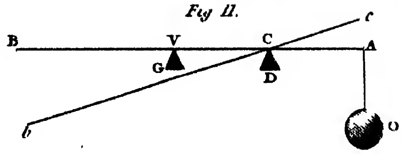


Fig 11.



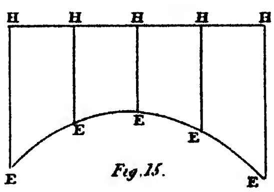


Fig.15.

PROJECTILES.

Fig 14.

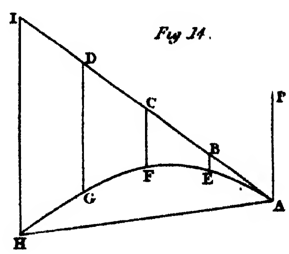


Fig. 17.

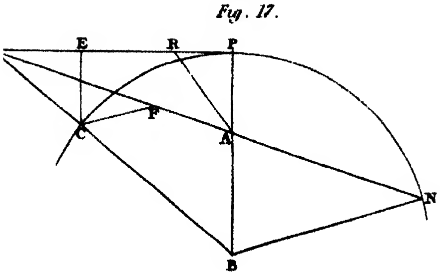


Fig 16

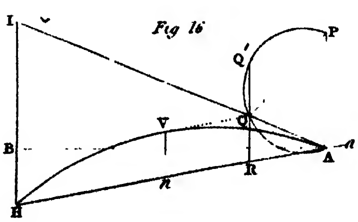


Fig. 15.

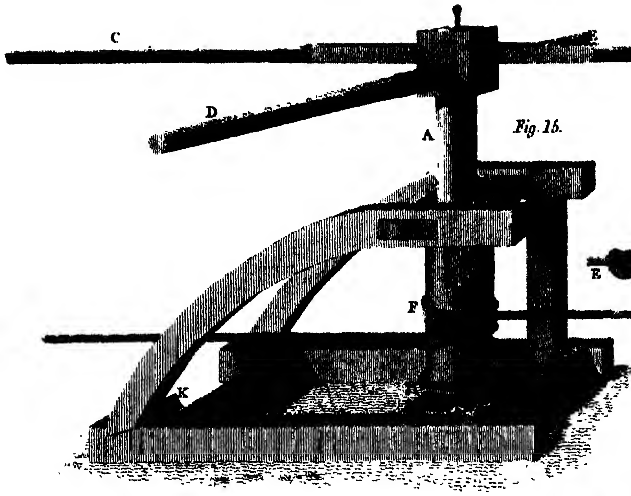
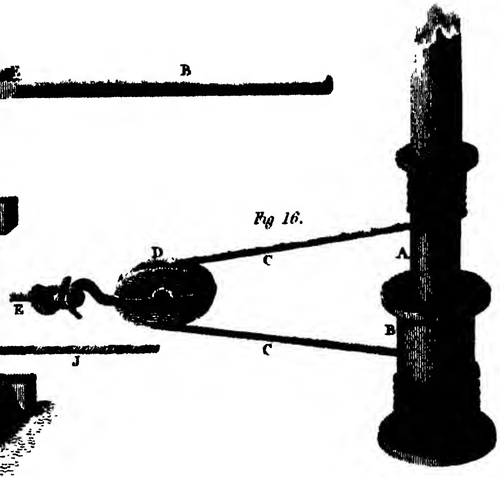


Fig. 16.



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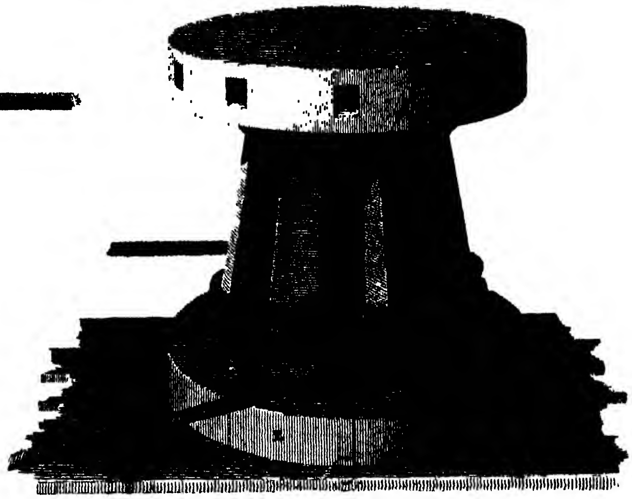
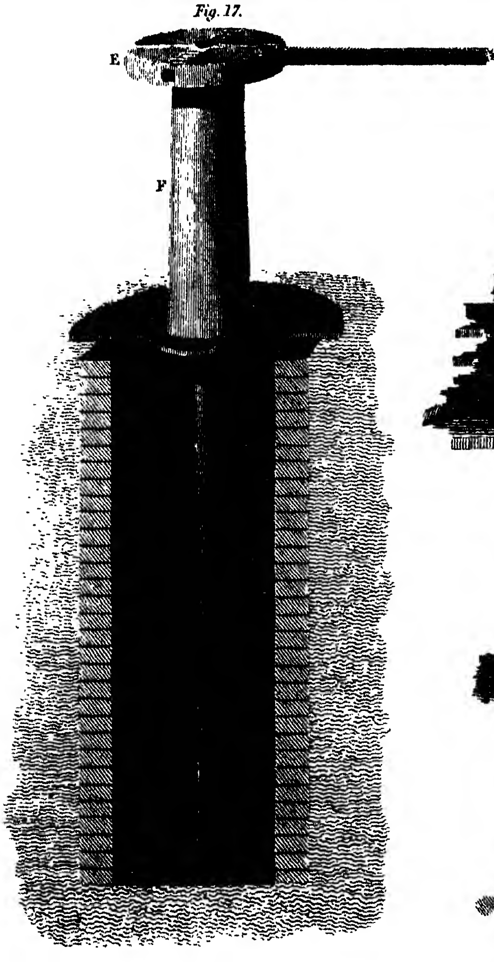


Fig. 17.



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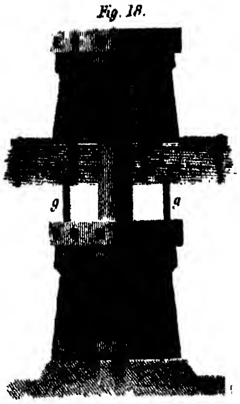


Fig. 19.

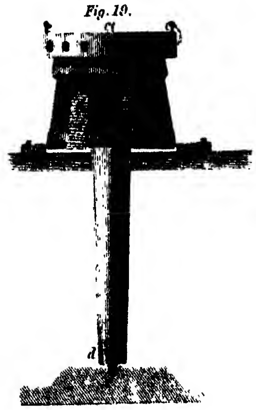
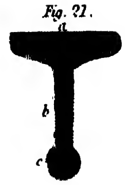


Fig. 21.



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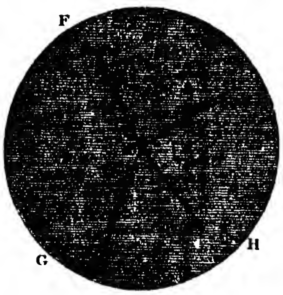
MECHANICS.

CENTER OF FRICTION, CENTER OF GRAVITY &c

Fig. 21



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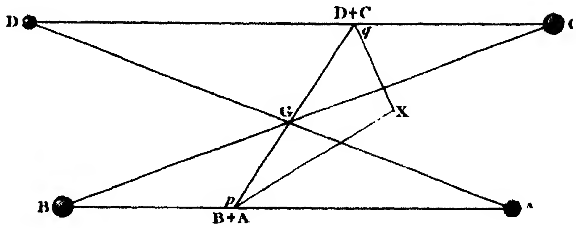


Fig. 23.

Fig. 24.

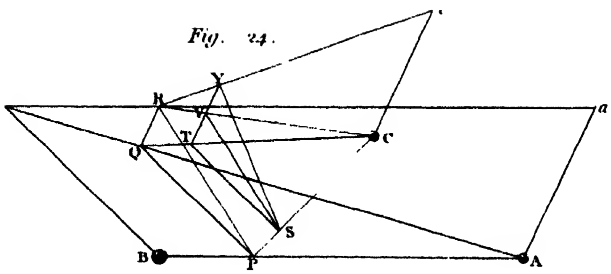
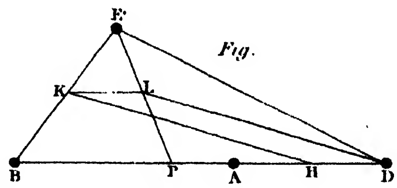


Fig.



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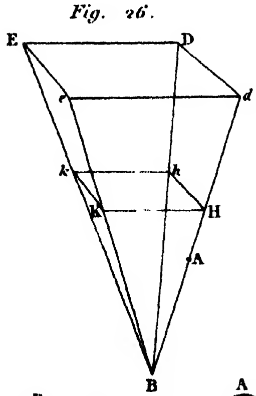
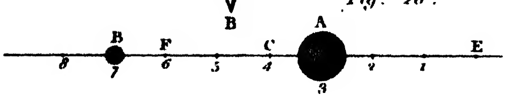


Fig. 27.

Fig. 28.



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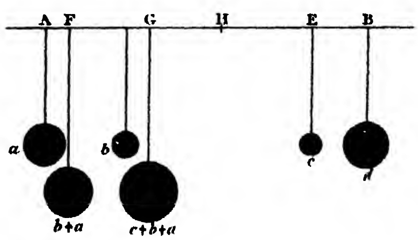

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MECHANICS.

CENTER OF GRAVITY.

Fig. 30.

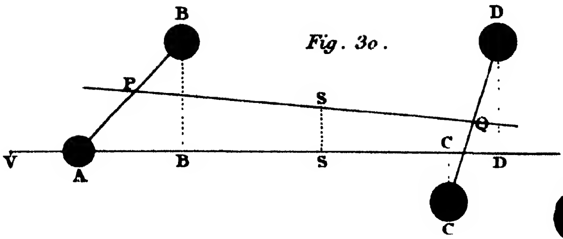
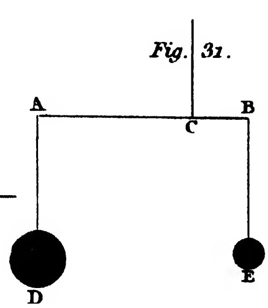


Fig. 31.



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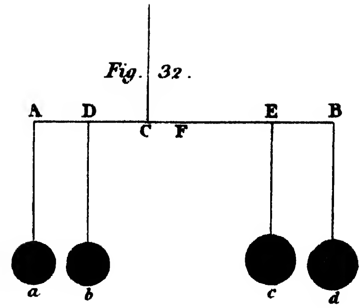
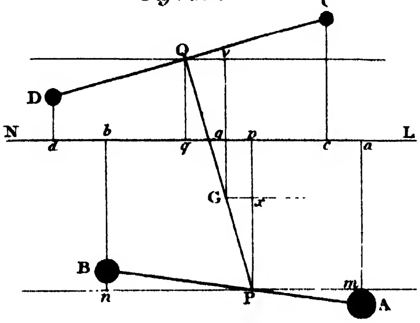


Fig. 33.



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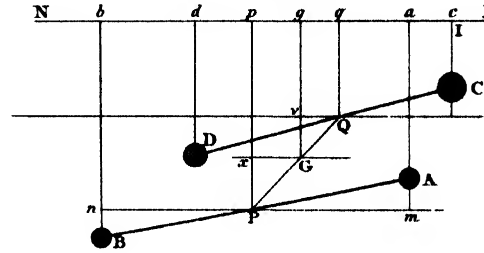

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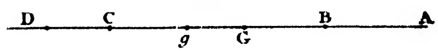

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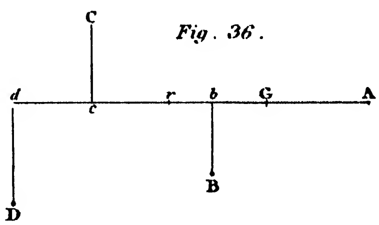


Fig. 37.

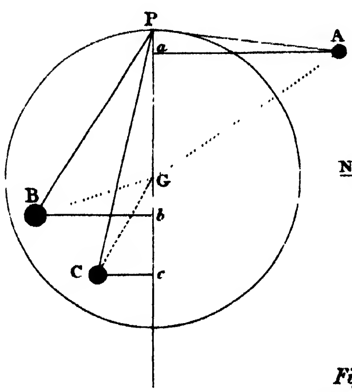
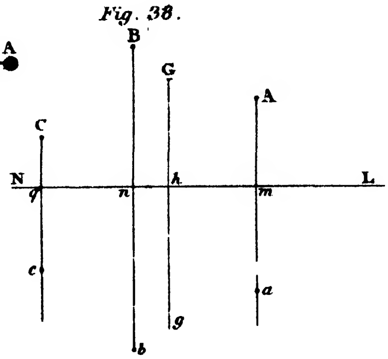


Fig. 38.



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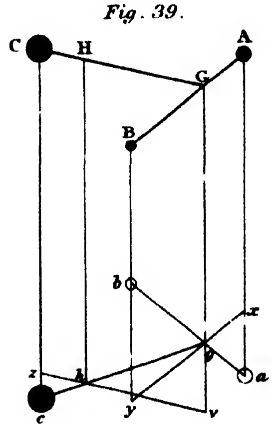

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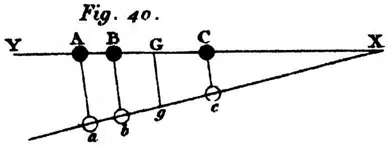

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MECHANICS.

CENTER OF GRAVITY.

Fig. 41

C

Fig. 42.

Fig. 43.

Fig. 44.

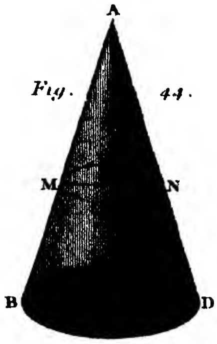


Fig. 45.

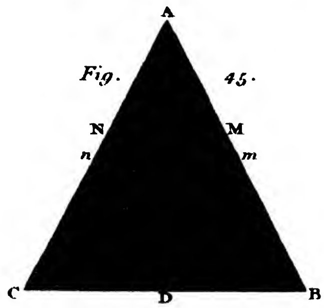


Fig. 46

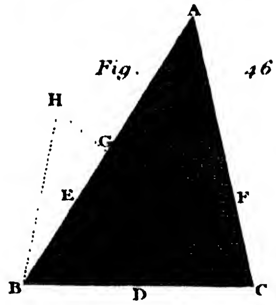
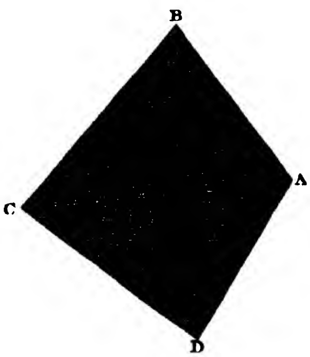


Fig. 47.



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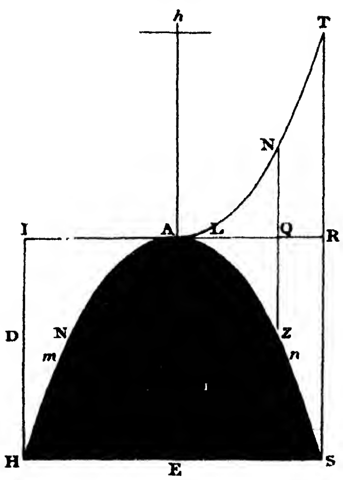


Fig. 49.

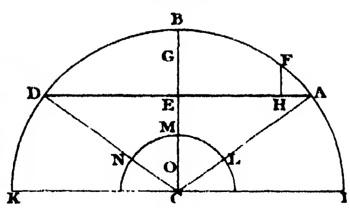


Fig. 50.

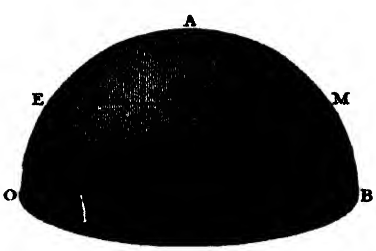
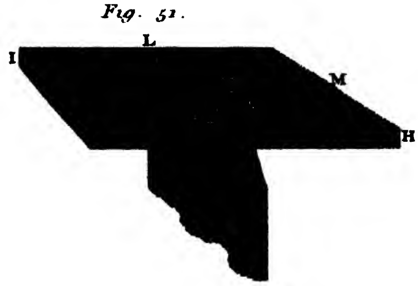


Fig. 51.



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MECHANICS.

CENTER OF GYRATION, OSCILLATION &c.

Fig. 54.

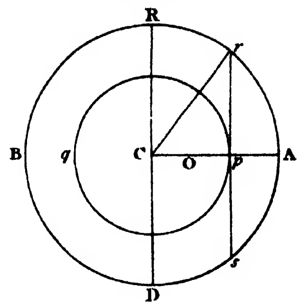


Fig. 52.

Fig. 53.

Fig. 55.

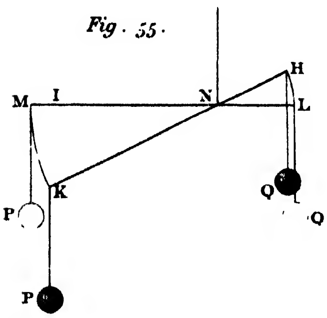
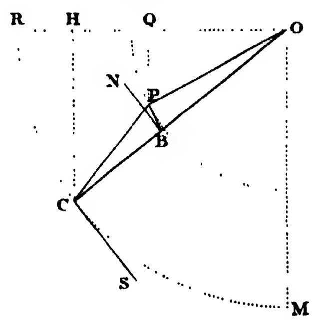


Fig. 56.

Fig. 57.



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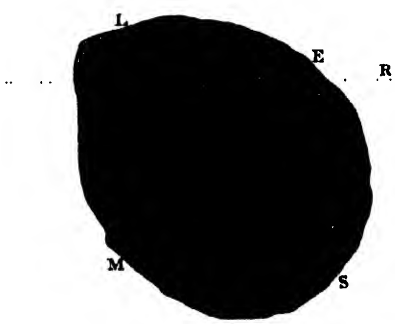
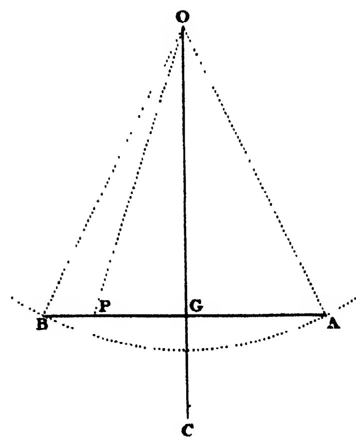


Fig. 59.

Fig. 60.



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CENTER OF OSCILLATION AND CENTER OF PERCUSSION.

Fig. 61.

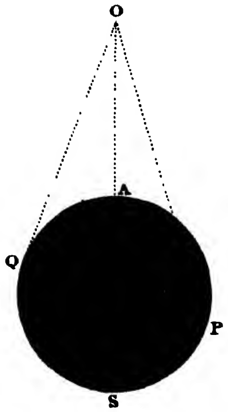


Fig. 62.

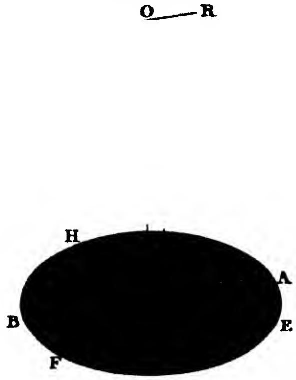


Fig. 63.

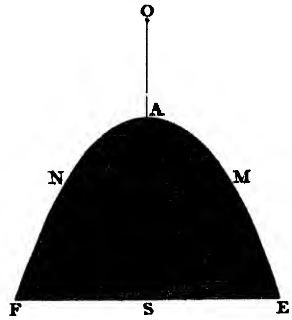


Fig. 64

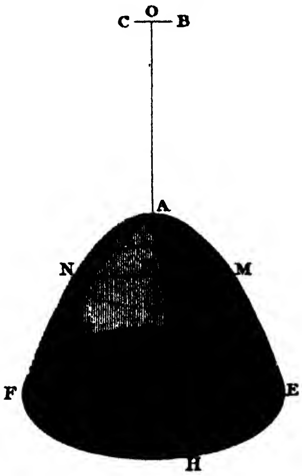


Fig. 65.

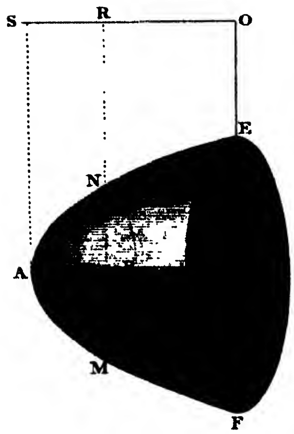


Fig. 66.

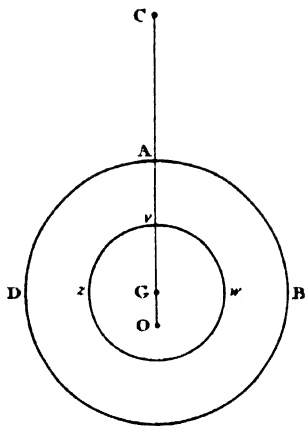


Fig. 67.

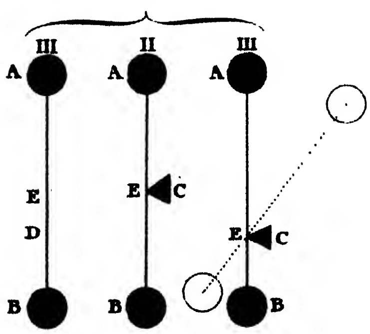


Fig. 68.

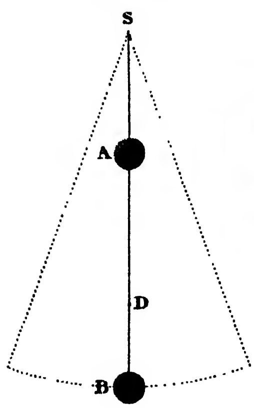
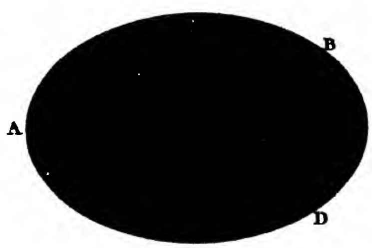


Fig. 69.



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MECHANICS.

CENTER OF POSITION, OF PRESSURE, OF ROTATION &c.

Fig. 70.

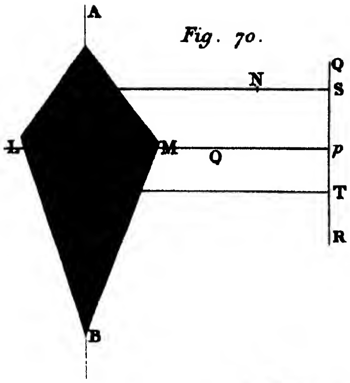


Fig. 71.

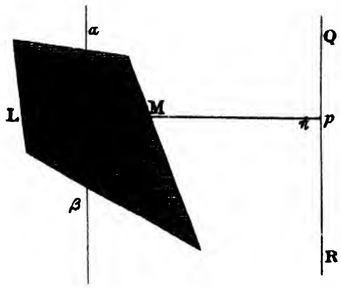


Fig. 72.

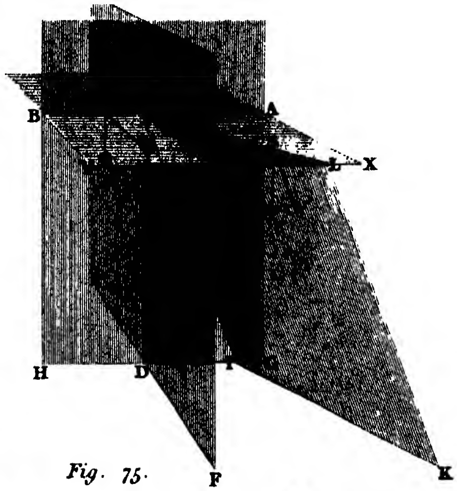


Fig. 73.

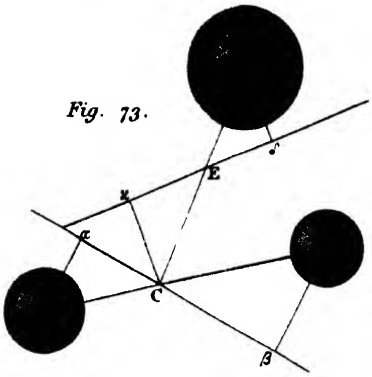


Fig. 74.

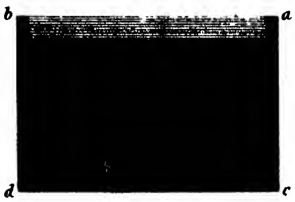


Fig. 75.

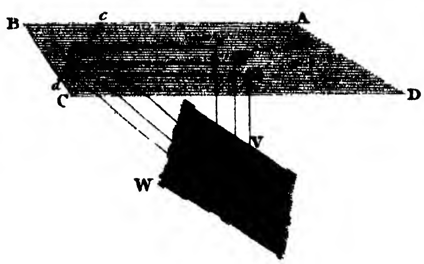


Fig. 76.

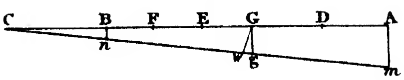


Fig. 77.

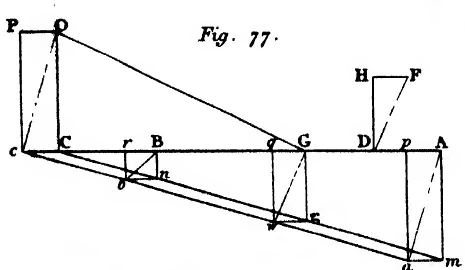


Fig. 78.

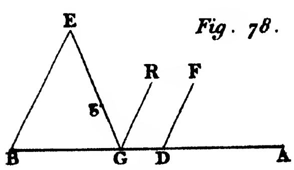


Fig. 79.

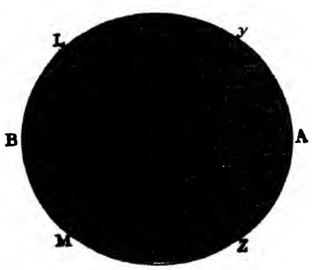
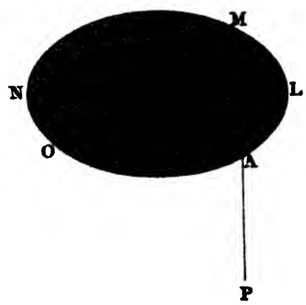


Fig. 80.



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CENTRAL, CENTRIFUGAL, AND CENTRIPETAL FORCES.

Fig. 81.

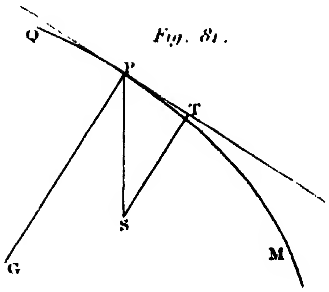


Fig. 82.

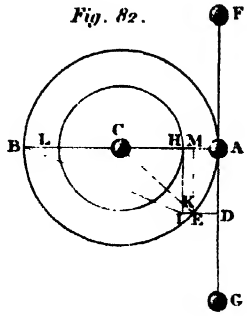


Fig. 83.

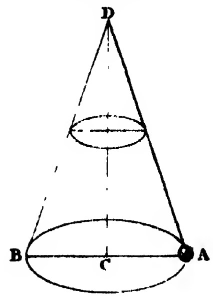


Fig. 84.

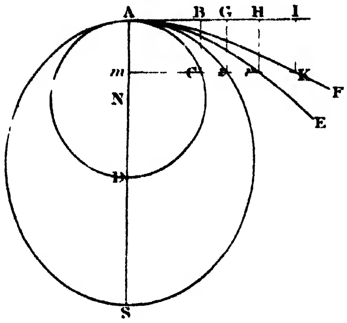


Fig. 85.

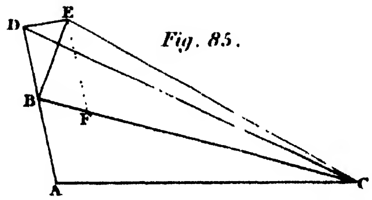


Fig. 86.

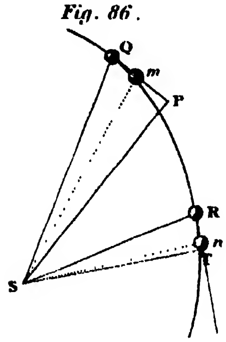


Fig. 87.

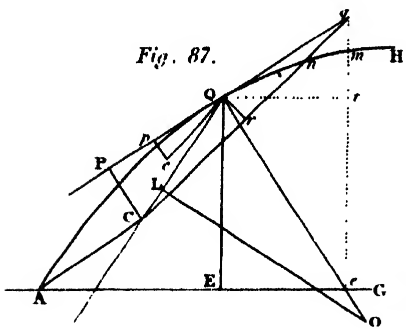


Fig. 88.

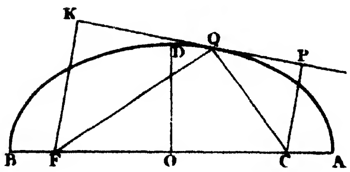


Fig. 89.

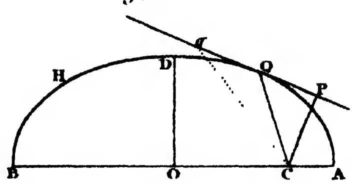


Fig. 90.

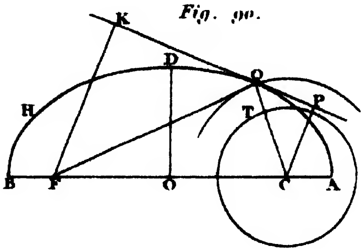


Fig. 91.

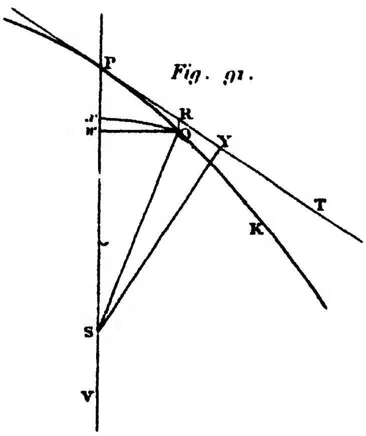
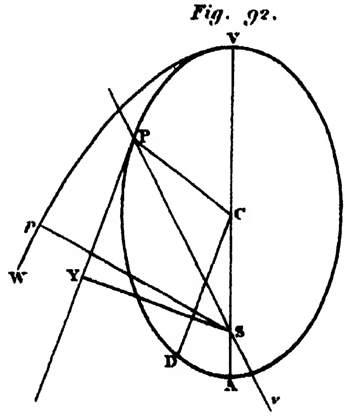


Fig. 92.



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MECHANICS.

CENTRIFUGAL MACHINE AND CENTROBARYC METHOD.

Fig. 93.

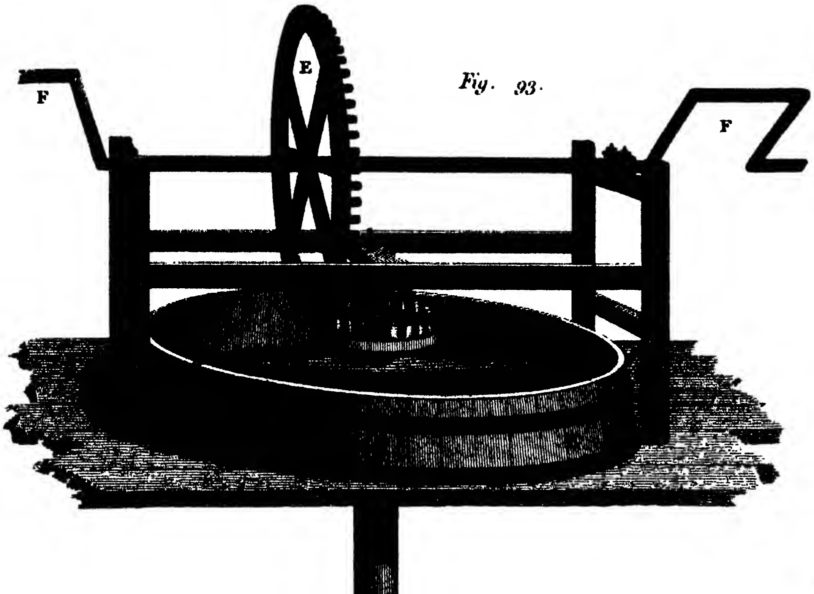


Fig. 94.

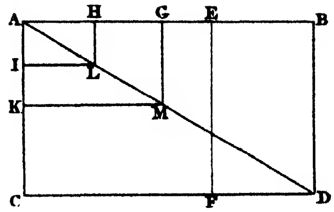


Fig. 95.

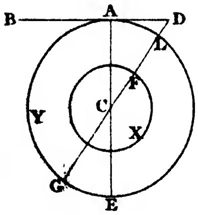


Fig. 96.

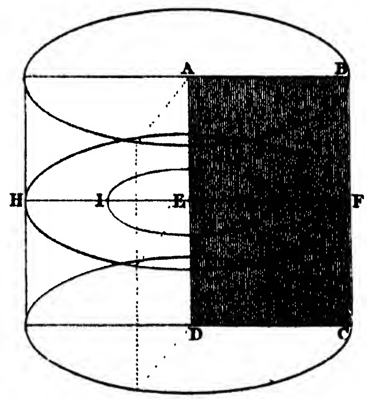


Fig. 97.

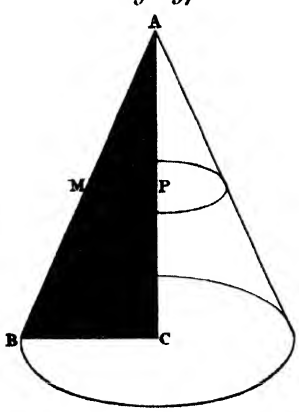


Fig. 98.

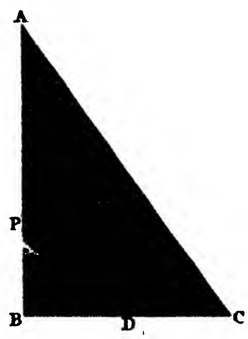
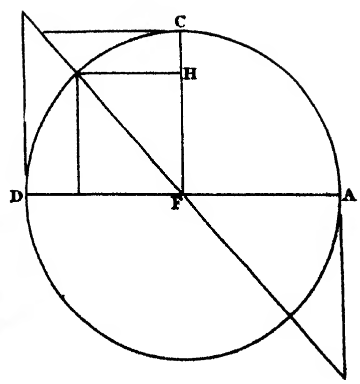


Fig. 99.



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COAL MEASURING.

Fig 1.

Fig. 2.

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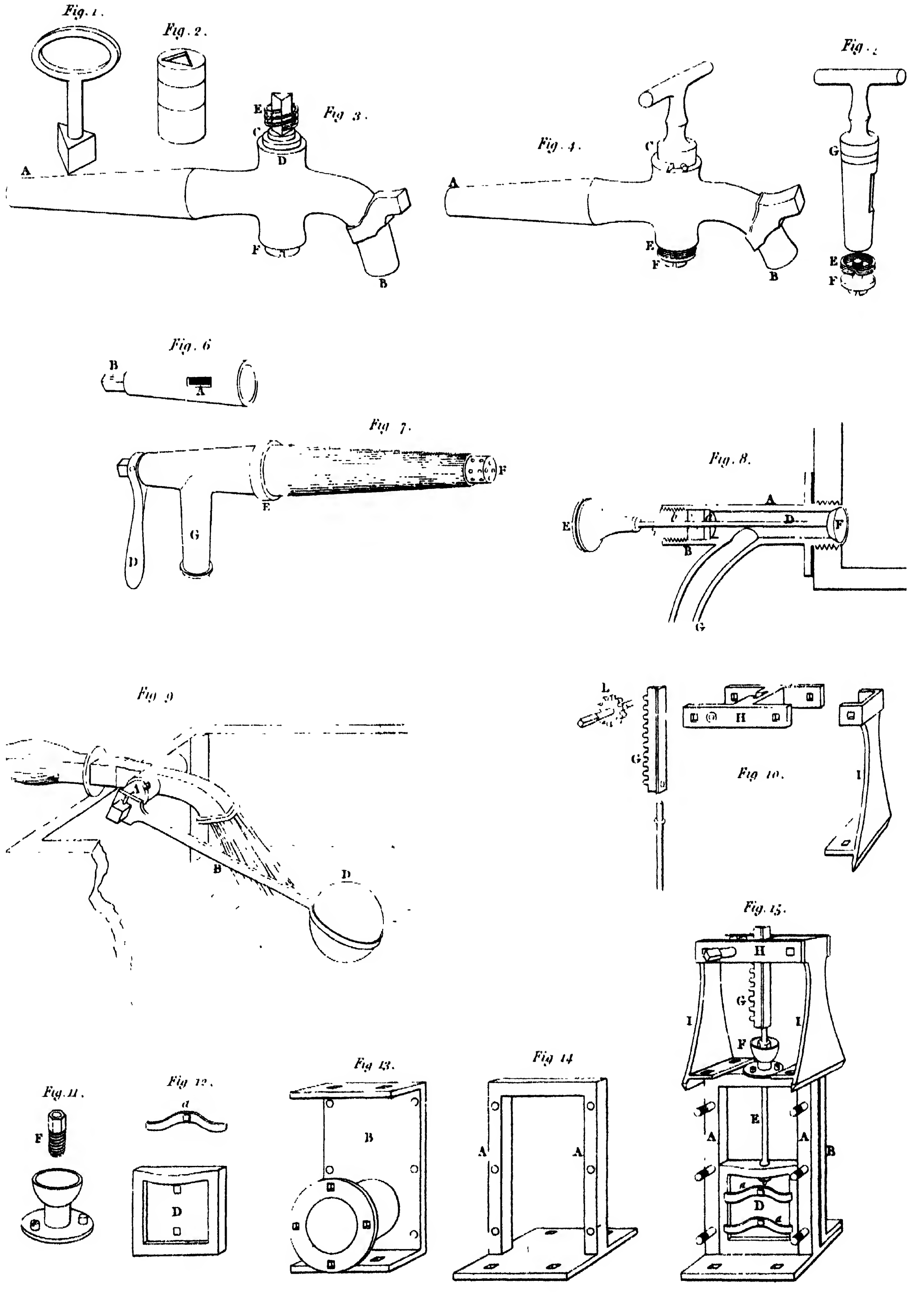
MECHANICS.

PLATE XIV.

WATER COCKS.



J. Farey Jun.r delin.

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Engraved by W. Lowry.

MECHANICS.

Prony's Condenser of Forces.

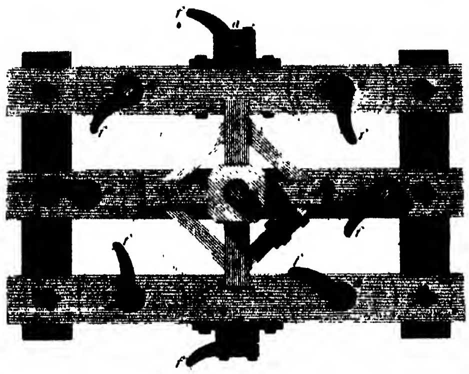


Fig. 10.

Composition of Motion.

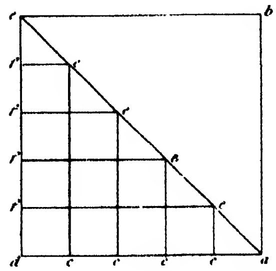
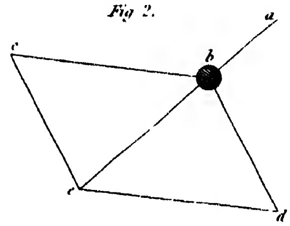
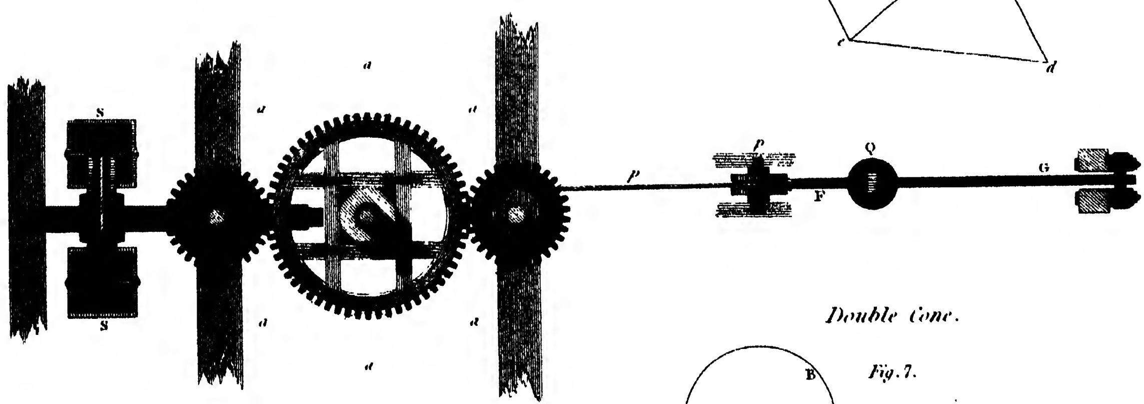


Fig. 1.

Fig. 2.

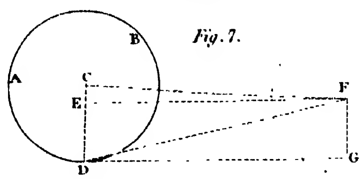


Plans.



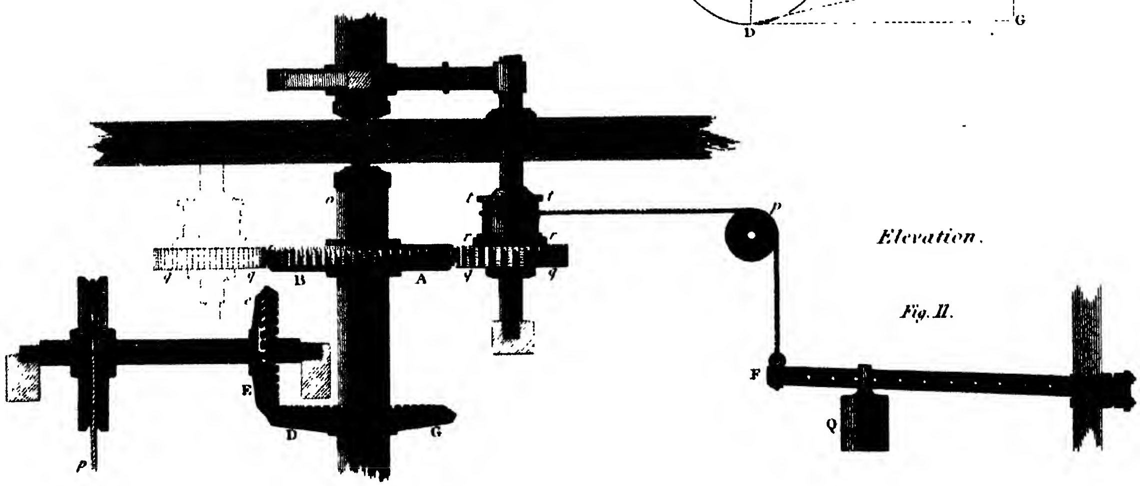
Double Cone.

Fig. 7.



Elevation.

Fig. 11.



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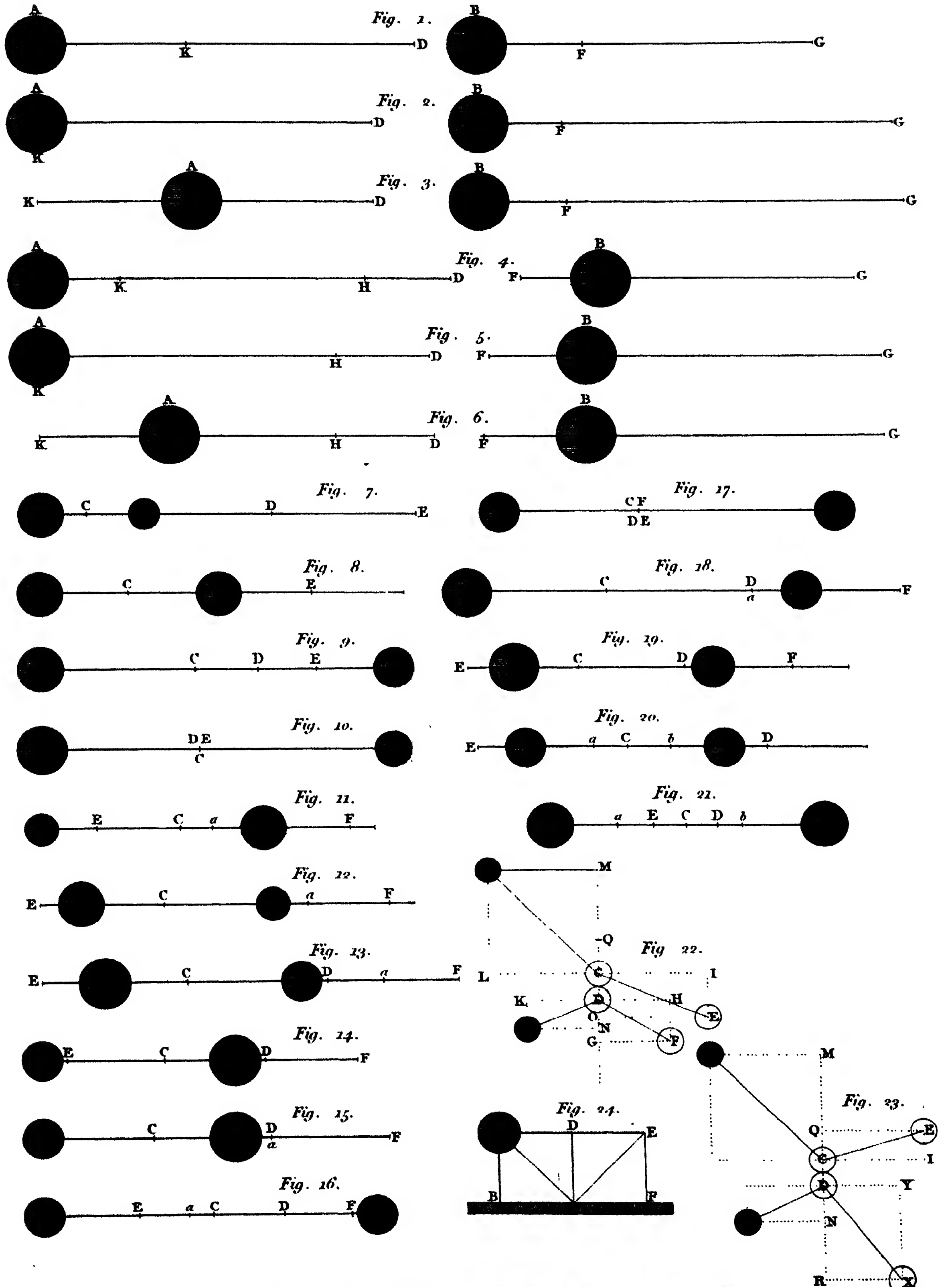
Lowry sculp.

MECHANICS.

COLLISION.



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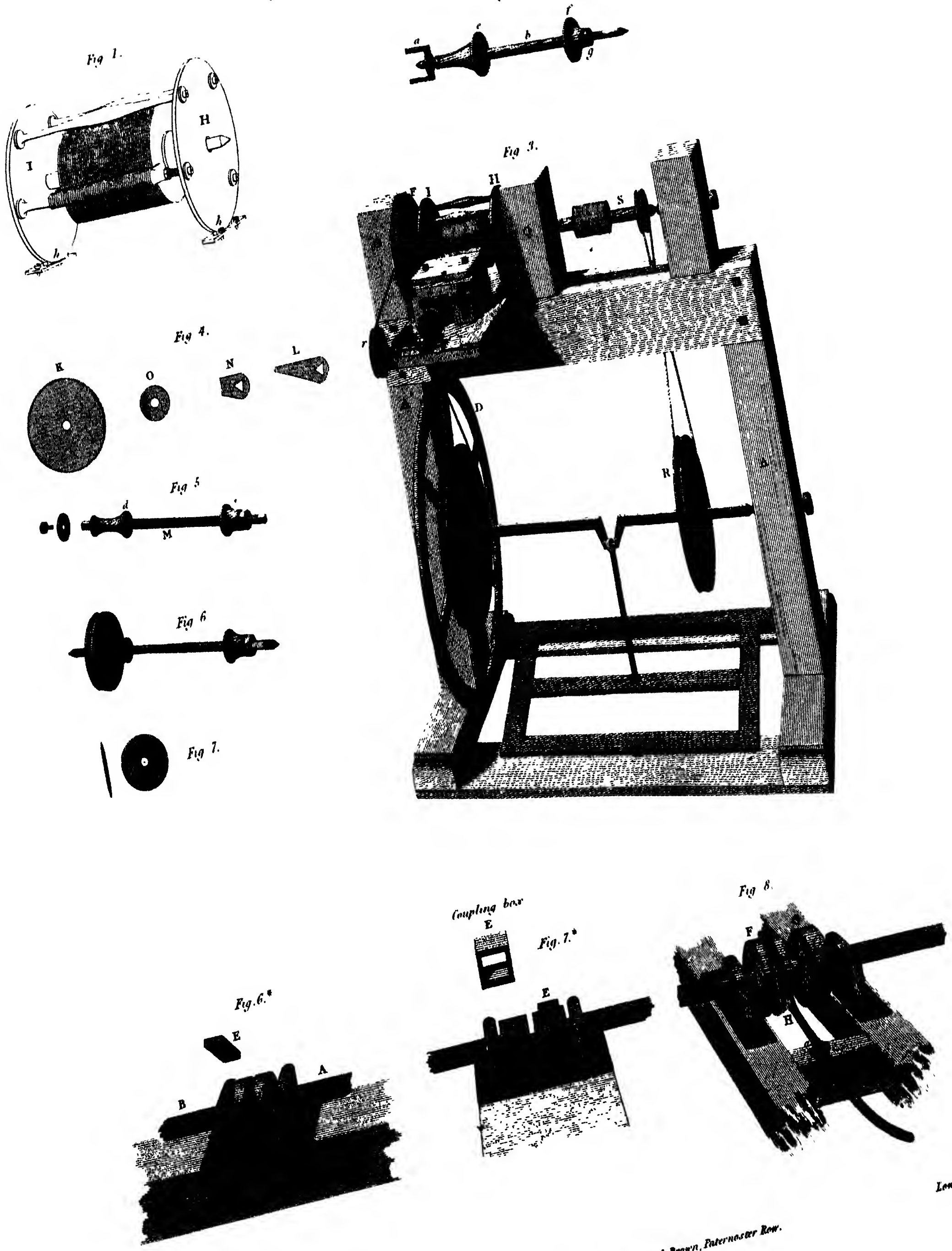
MECHANICS.

COMB MAKING.



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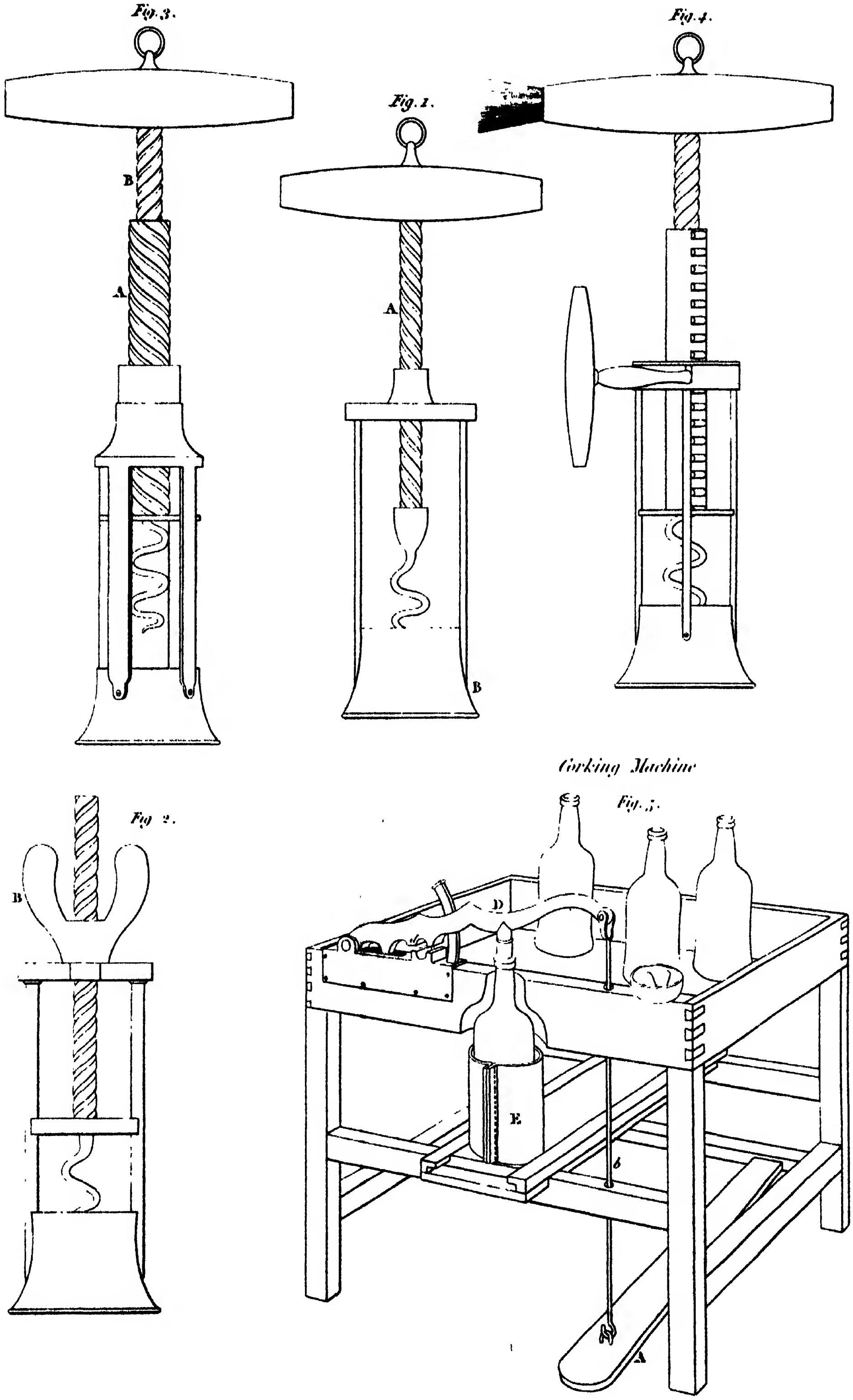


J. Farey Junr. delin. Published as the Act directs, 1810, by Longman, Hurst, Rees & Orme, Paternoster Row. Engraved by Wilson Lowry

MECHANICS

PLATE XVIII.

CRANES,

by M.r Ferguson.

Fig. 2.

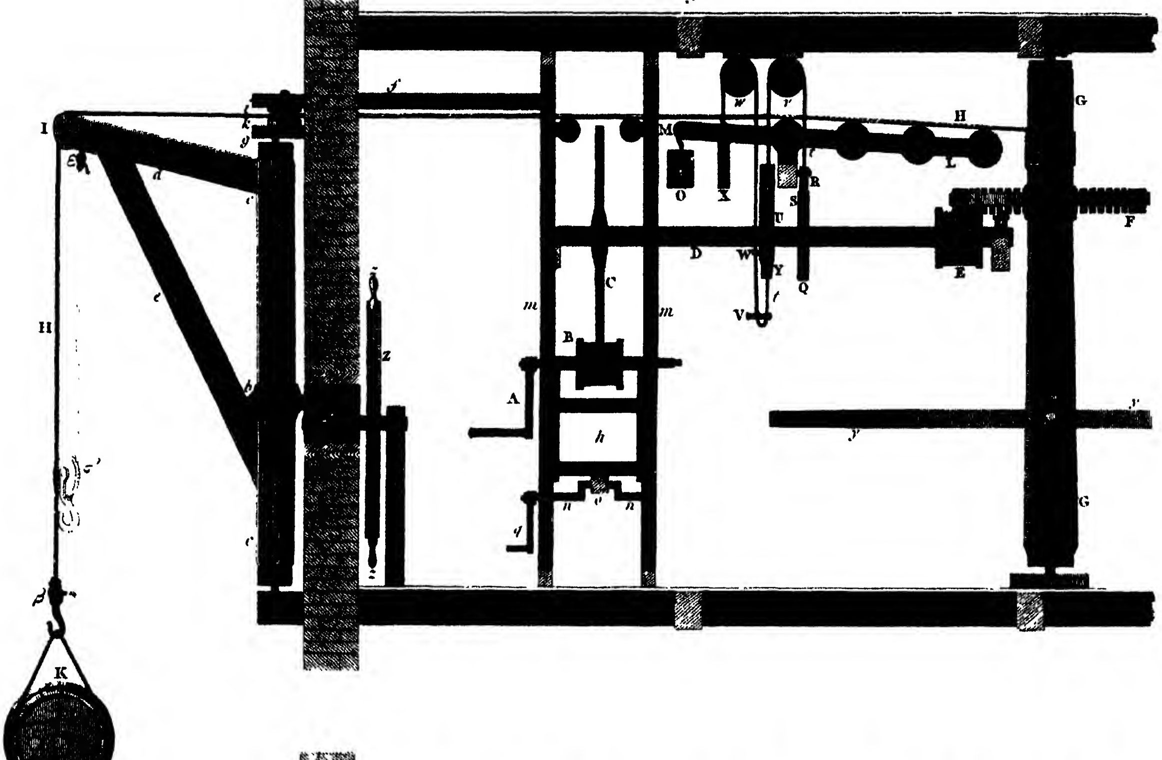
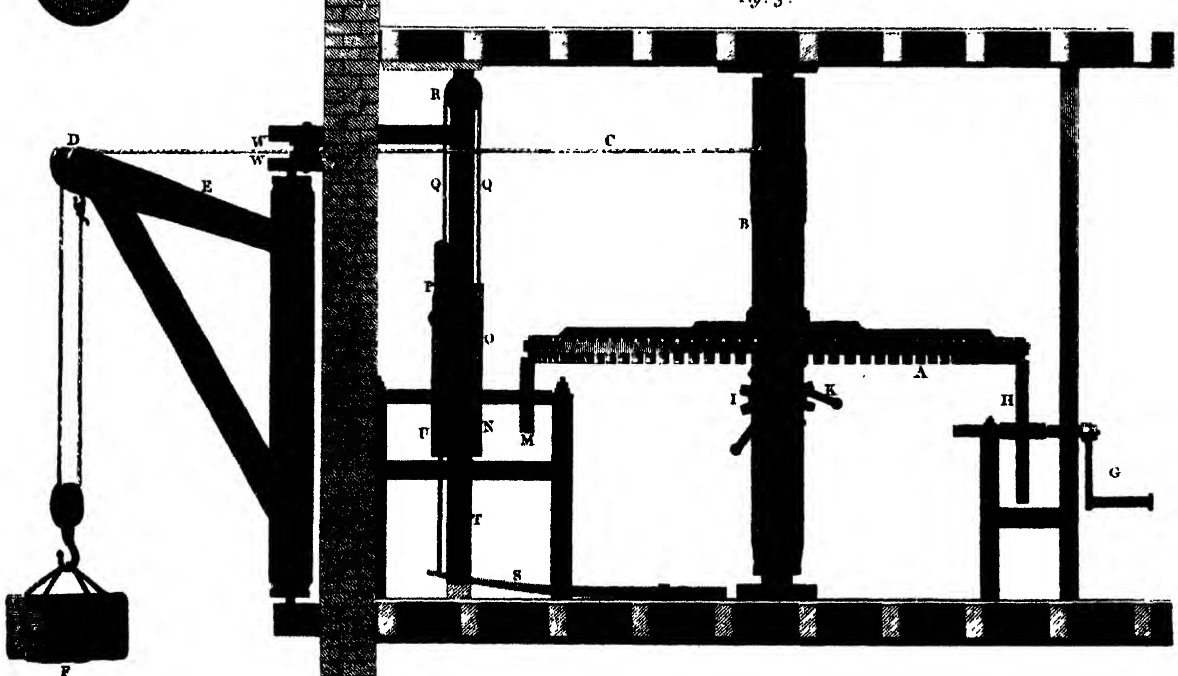


Fig. 3.



rey Jun.r delin.

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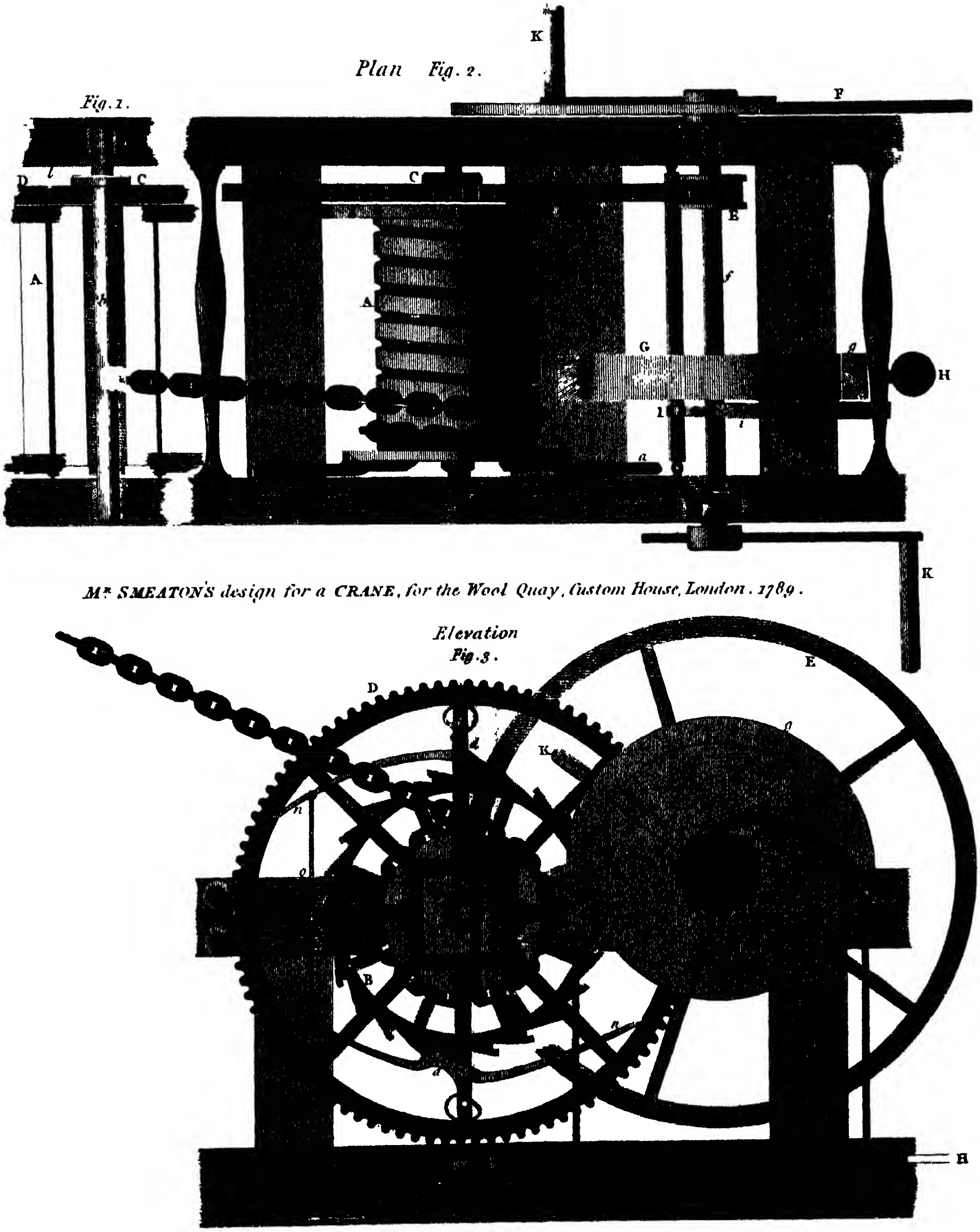
CRANES.

Plan Fig. 2.

Fig. 1.



Mr SMEATON'S design for a CRANE, for the Wool Quay, Custom House, London. 1789.

Elevation Fig. 3.

Scale of Inches.

10 20 30 40 60 70 80

Reduced by permission from the Original Drawing in the possession of Sir Joseph Banks K.B. by J. Farey Junior.

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CRANES.

Fig. 1.

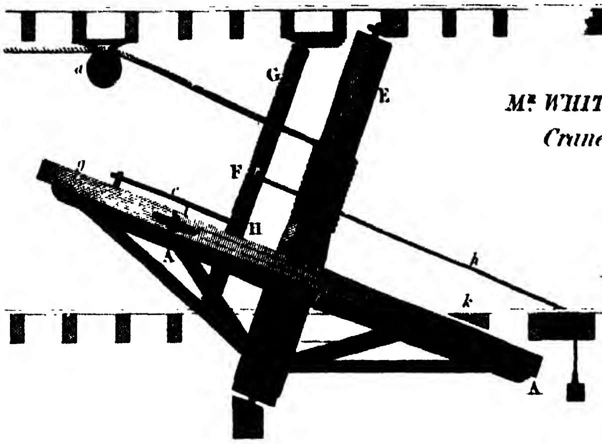
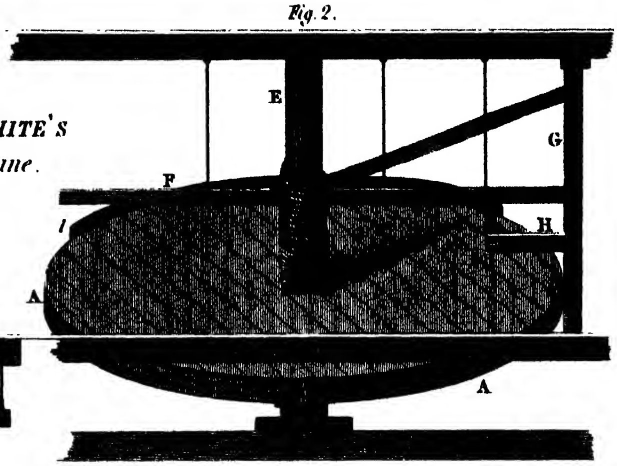
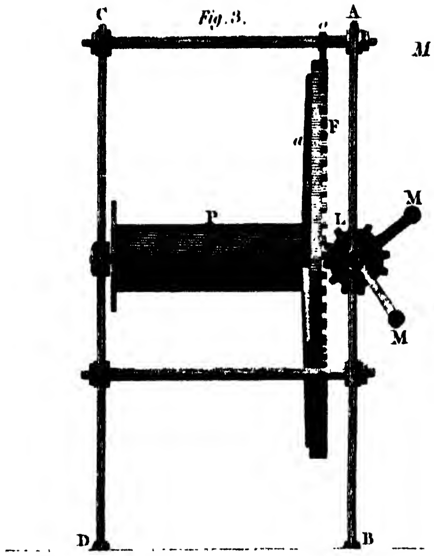


Fig. 2.



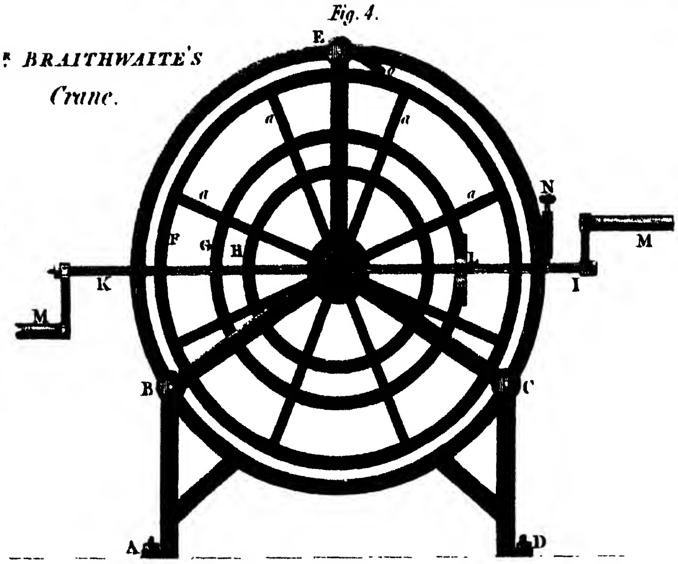
Mr. WHITE'S Crane.

Fig. 3.



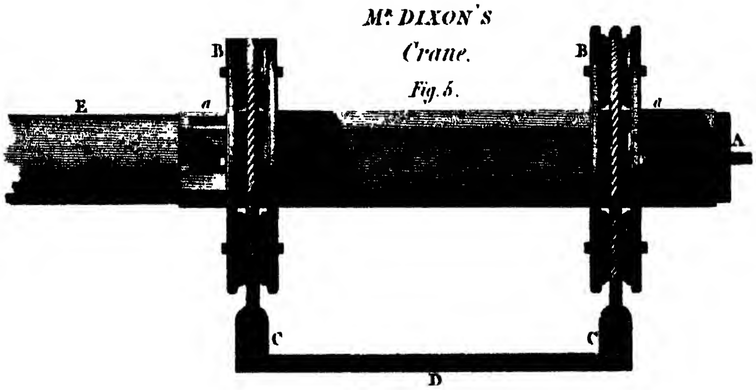
Mr. BRAITHWAITE'S Crane.

Fig. 4.



Mr. DIXON'S Crane.

Fig. 5.



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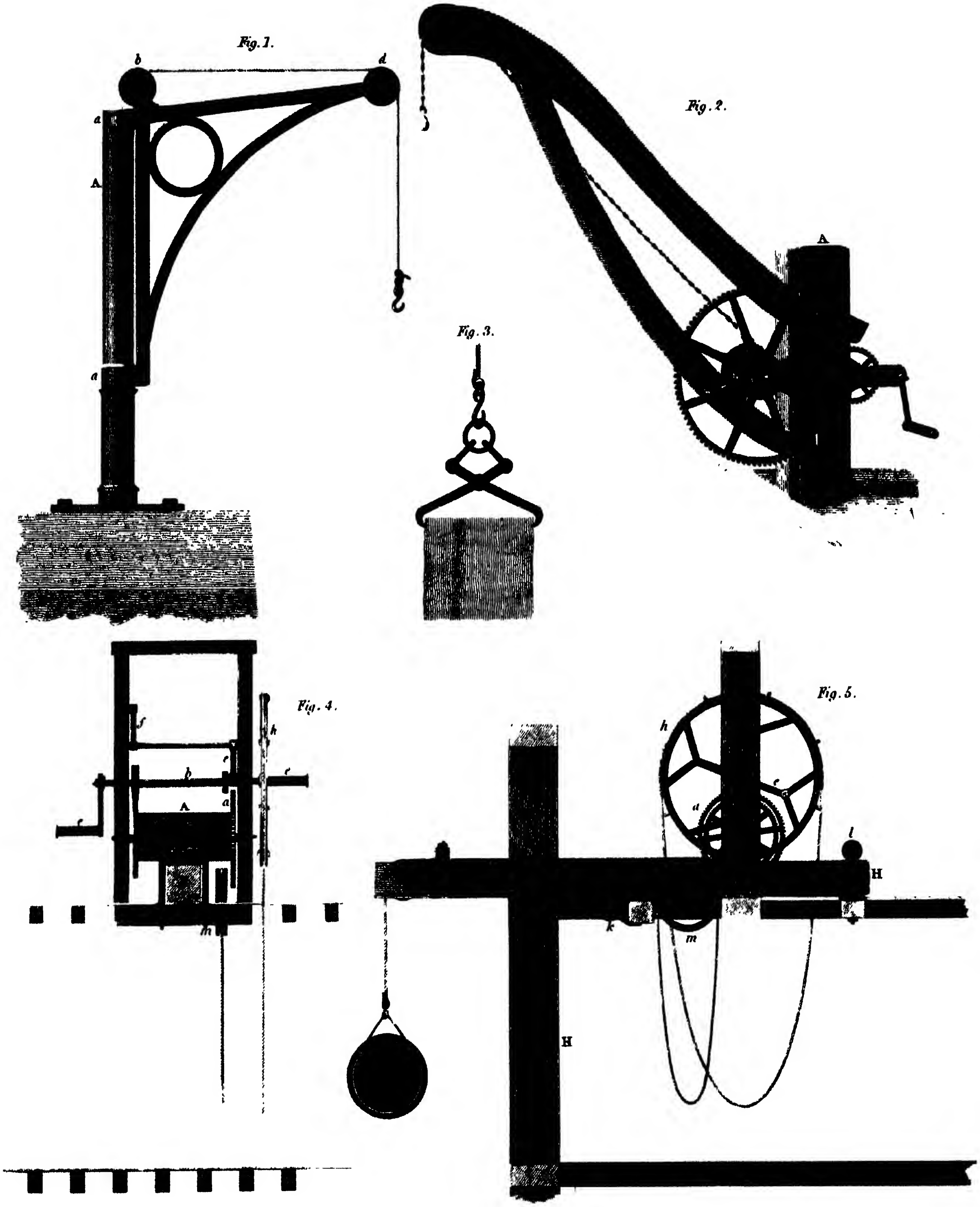
CRANES.



...y Jun.r delin.

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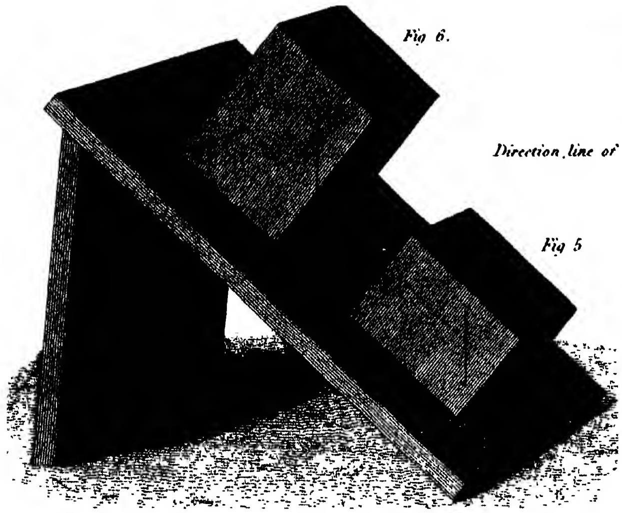
Engraved by Wilson Lowry.

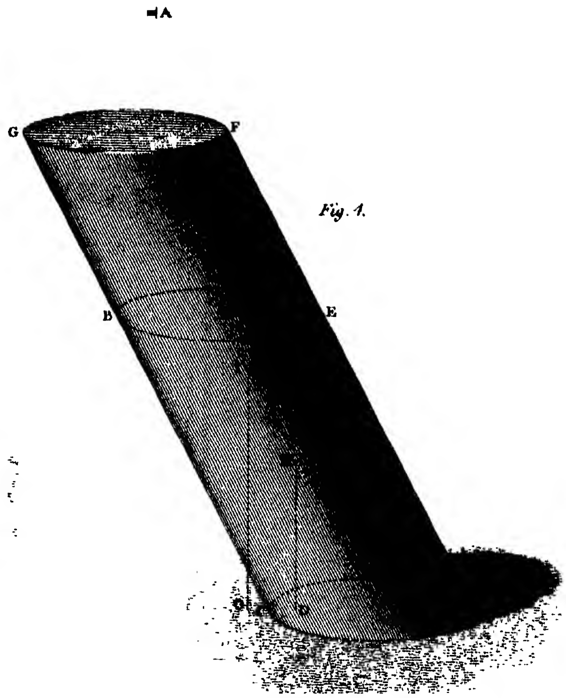
MECHANICS.

PLATE XXII & XXIII.

DIRECTION of Motion.

Fig. 3.

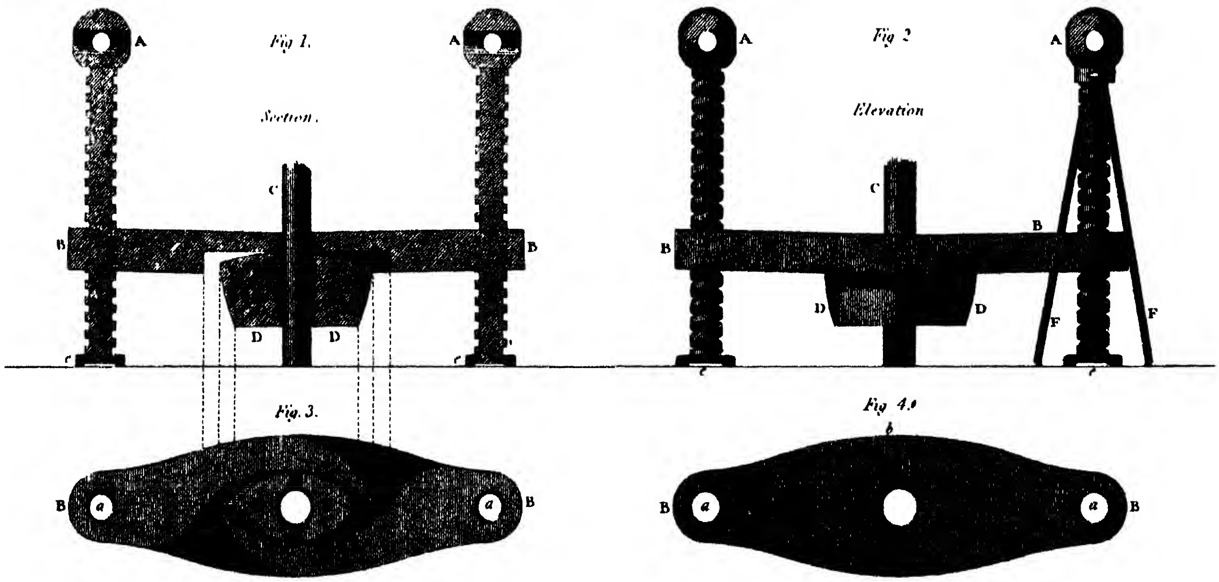




MECHANICS.

PLATE XXIII.

Mr. Hill's Machine for DRAWING out Ships Bolts.



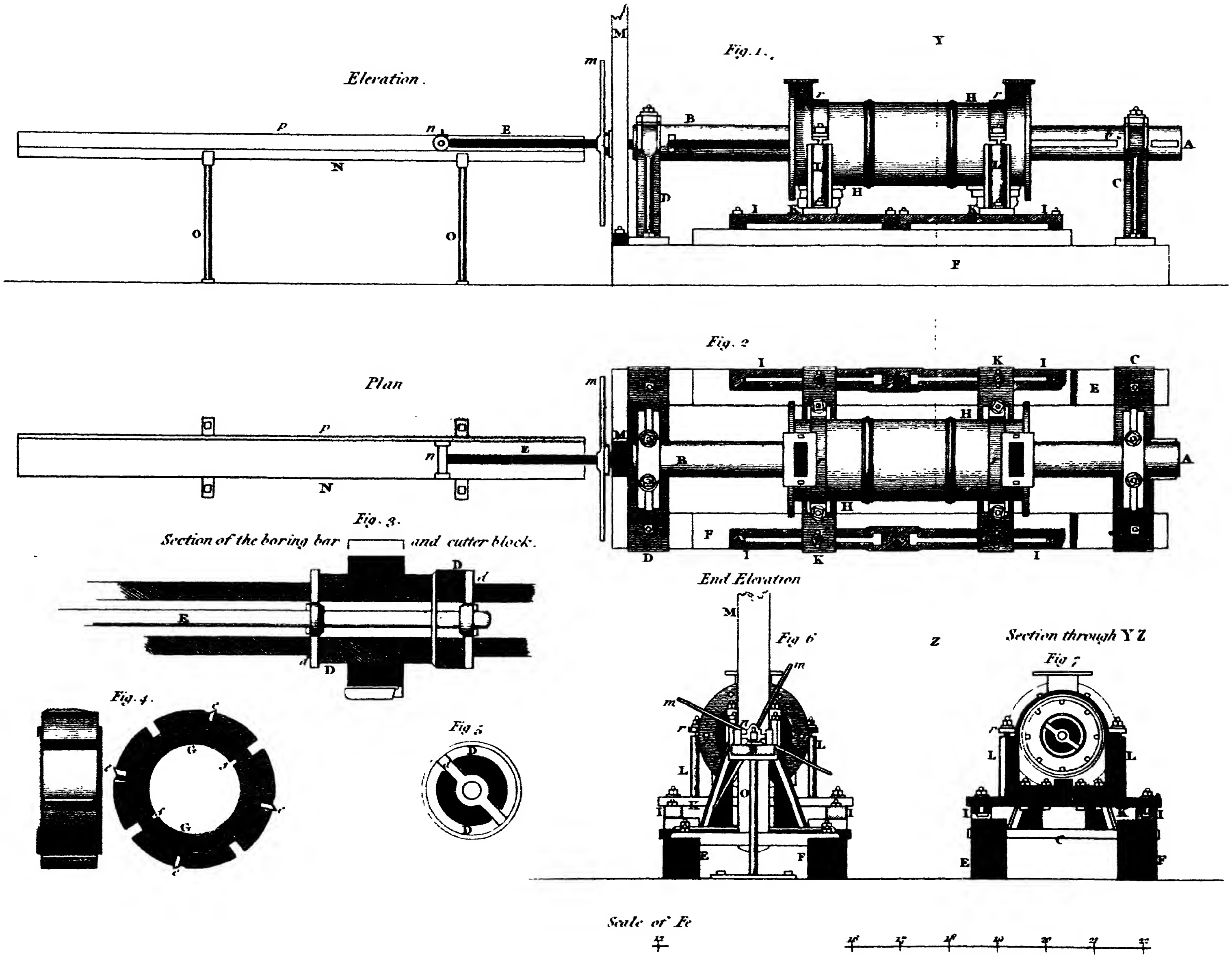
Plan of the lower Side.

Plan of the upper Side.

del. Published as the Act directs, 1814, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row, London. Lowry sculp.

MECHANICS.

Machine for boring Cylinders, at the Falcon Iron Foundery, made by M.r Dixon.



MECHANICS.

DYNAMICS.

PLATE XXV.

Fig. 1.

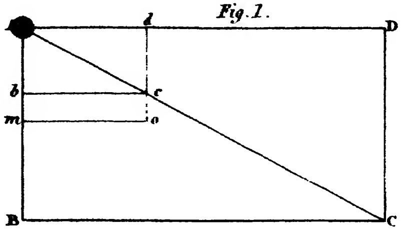


Fig. 2

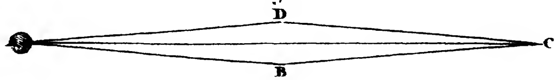


Fig. 3.

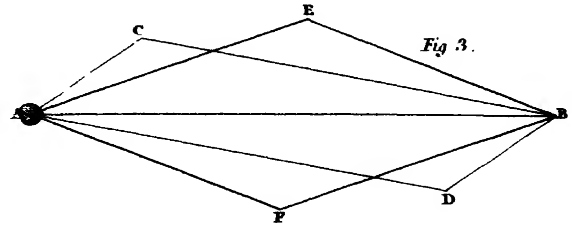


Fig. 4.

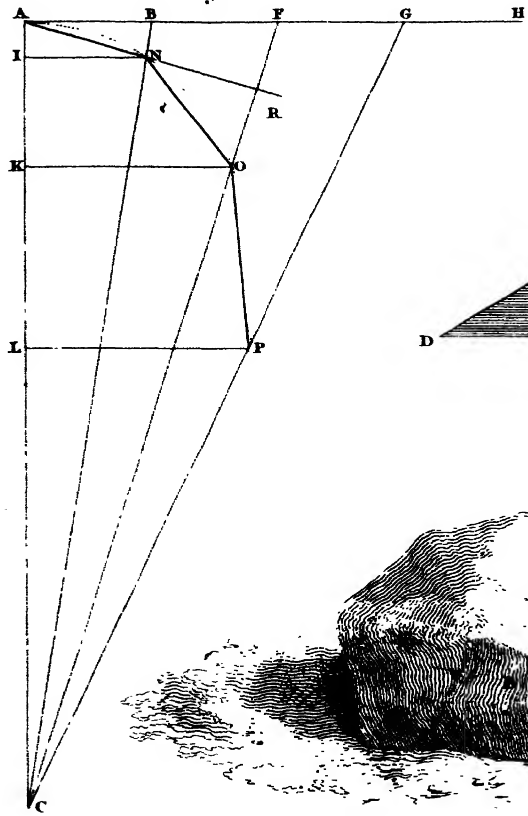


Fig. 5.

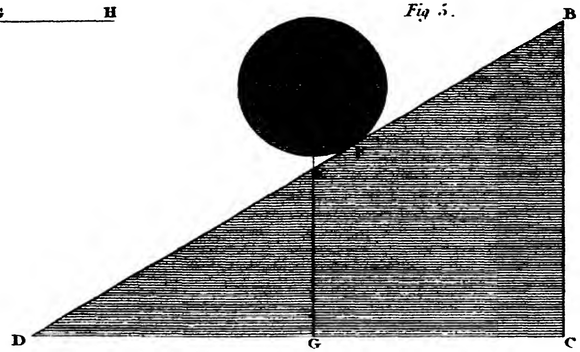


Fig. 6.

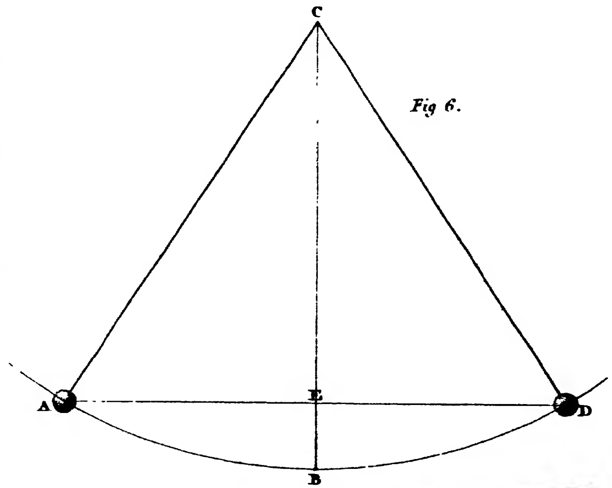
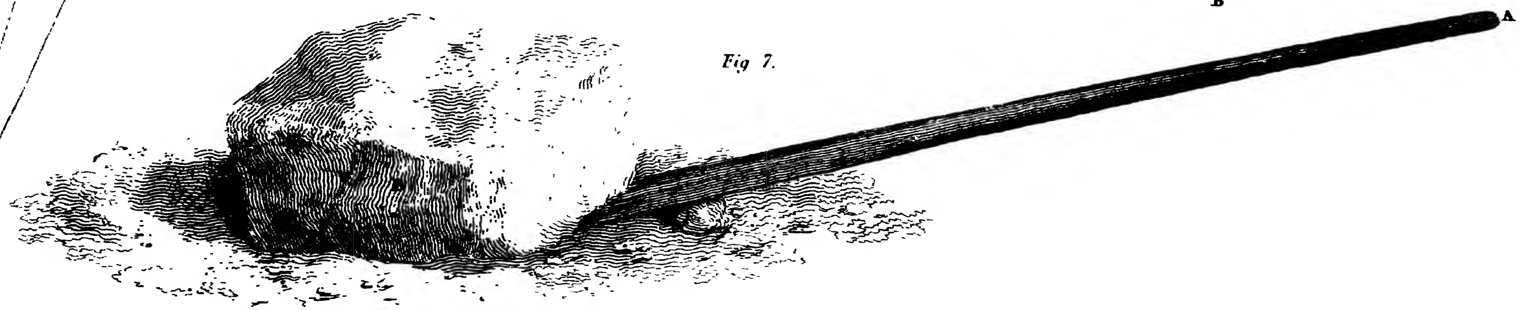


Fig. 7.



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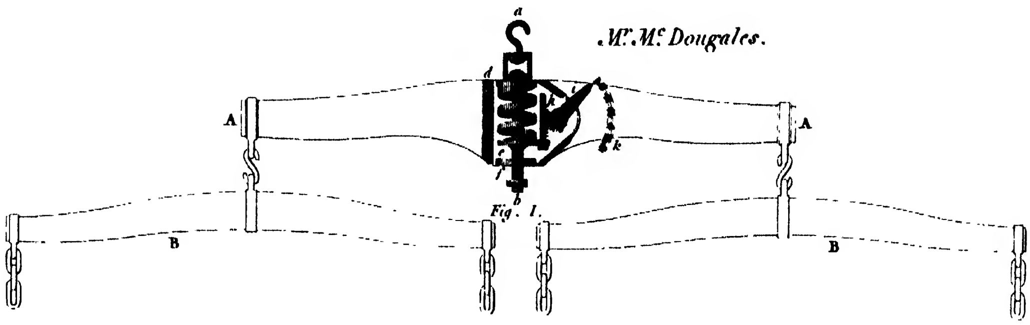
MECHANICS.

DYNANOMETERS.

PLATE XXV

FOR MEASURING THE FORCE OF DRAUGHT.



Mr. Mc Dougales.

Fig. 1.

Fig. 3.

Mr. Salmons contrivance for determining the force required to work a Mill.

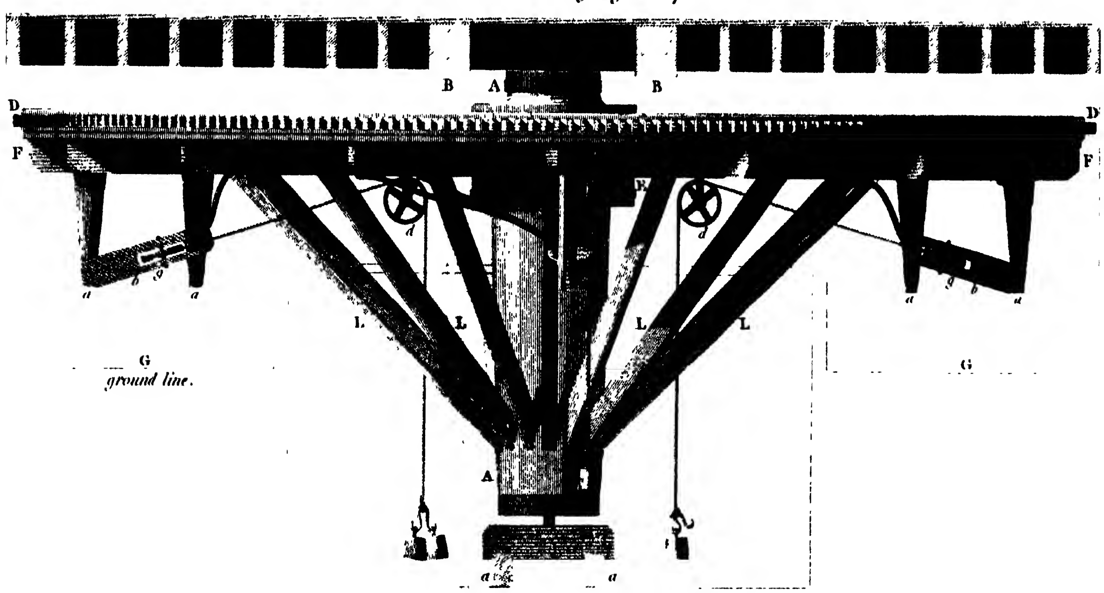
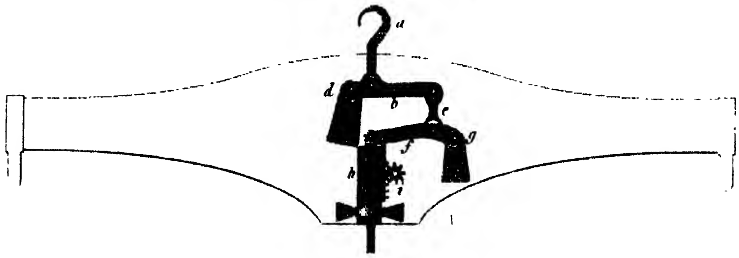


Fig. 2.

Mr. Salmons Dynanometer.



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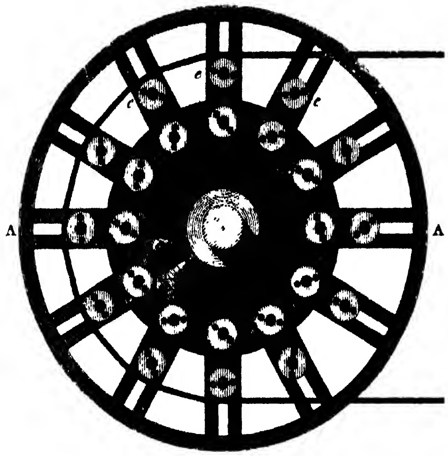
EXPANDING RIGGERS.

Fig. 5.



Mr A. Flints.

Fig. 6.

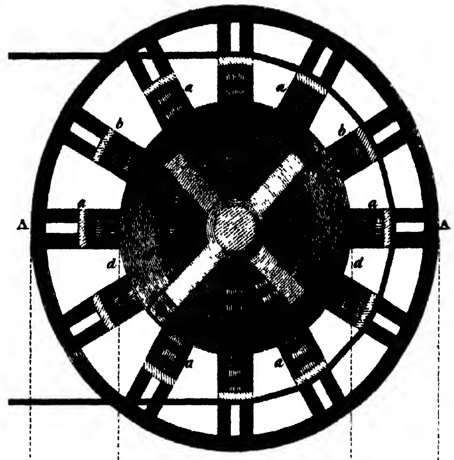


Fig. 10.

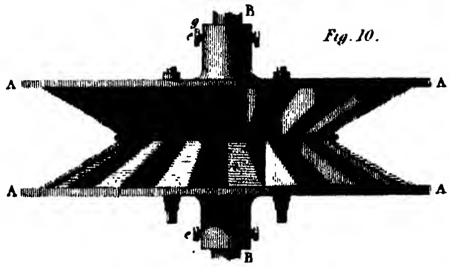


Fig. 7.

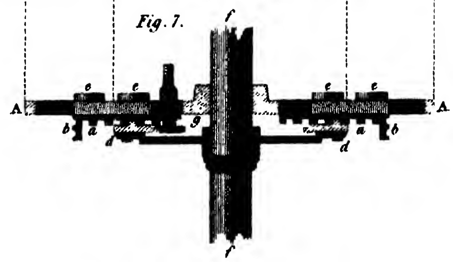


Fig. 11 Mr Farey's.

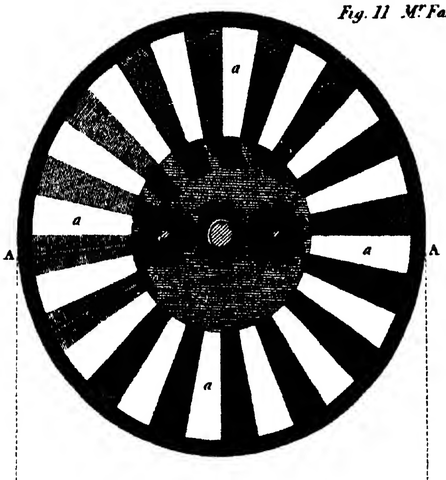


Fig. 8.

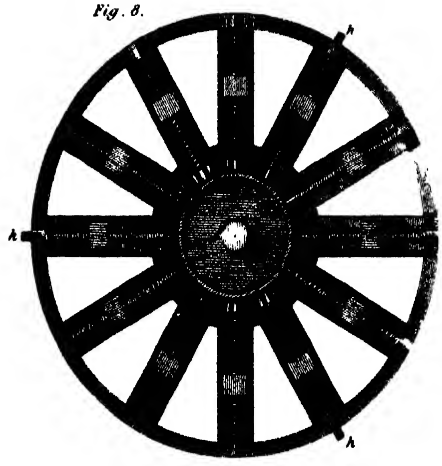


Fig. 12.

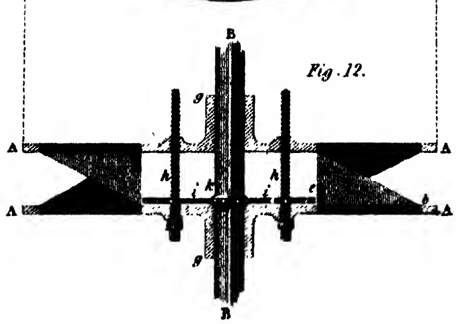
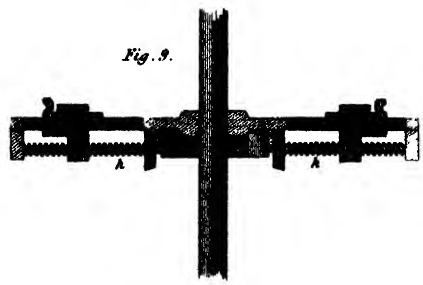


Fig. 9.



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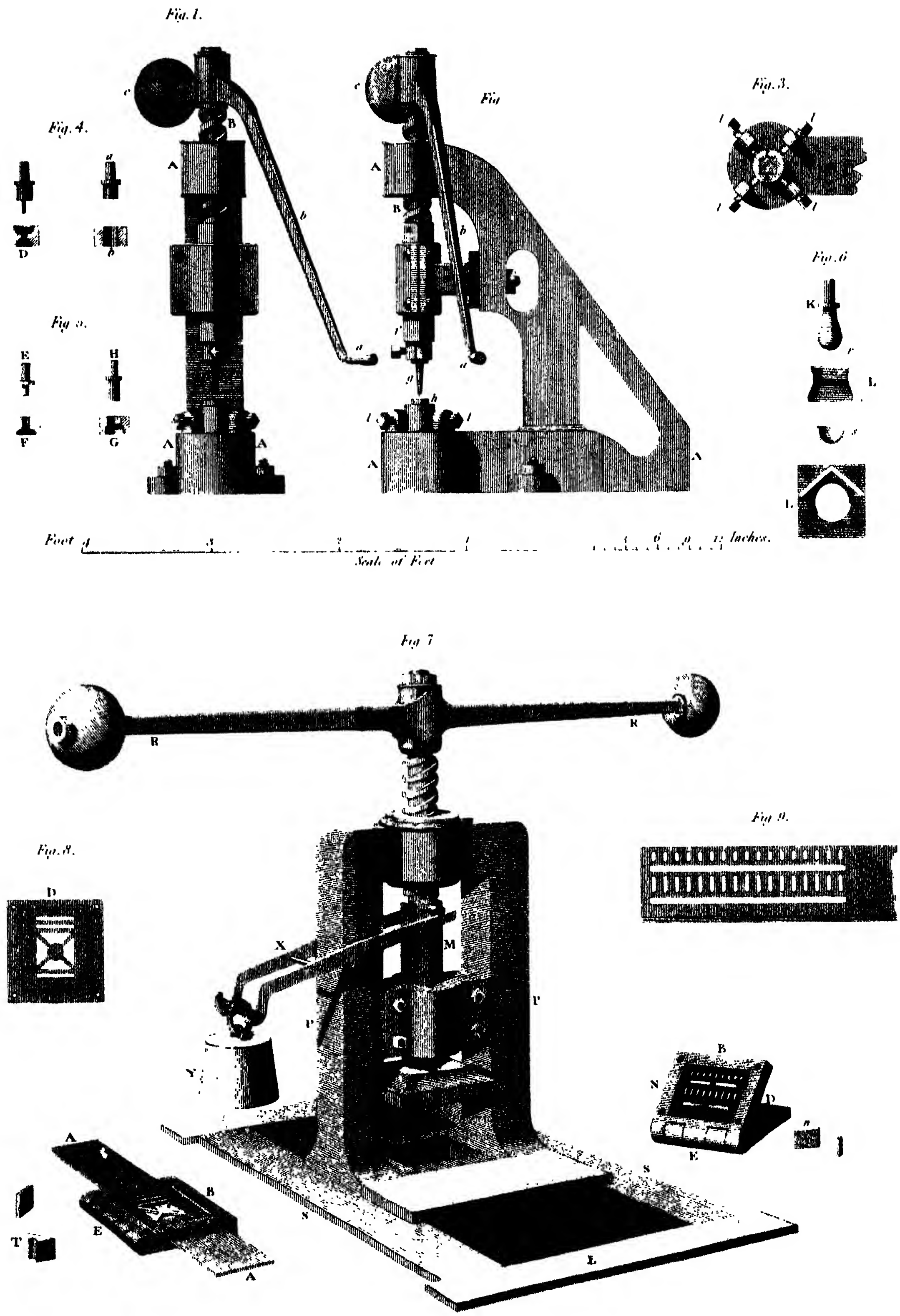
MECHANICS.

FLY-PRESS.

PLATE XXVII.



Farey del.

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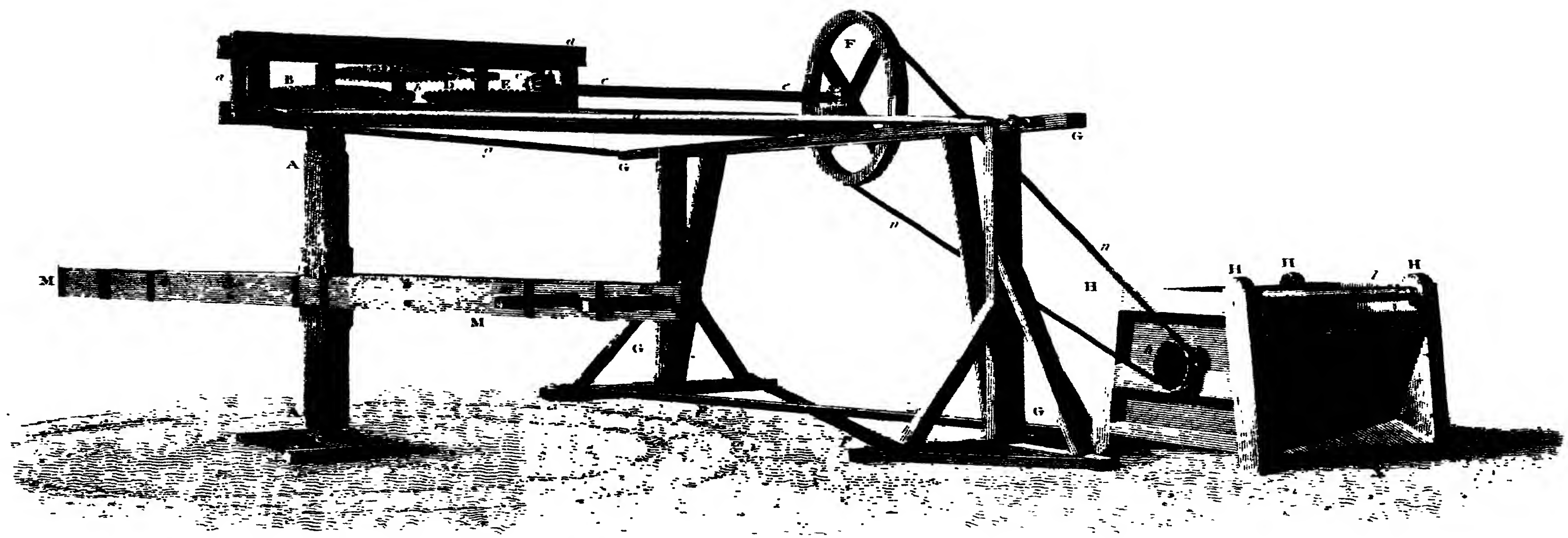
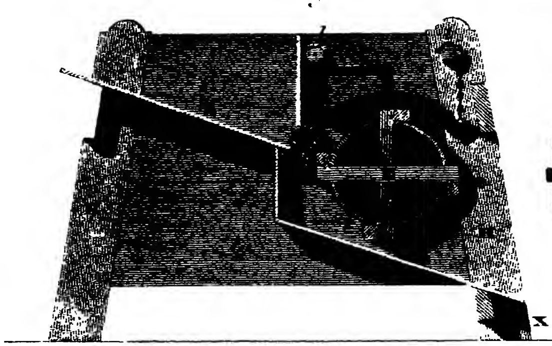
MECHANICS.

M^r. R. SALMON'S, PORTABLE THRASHING MILL.

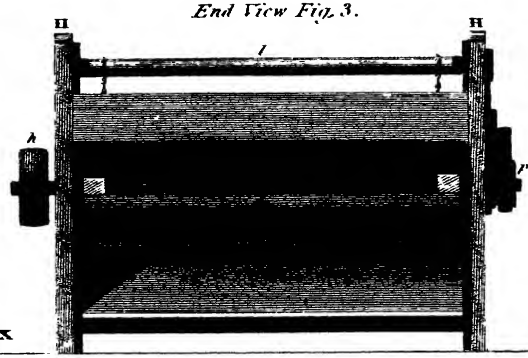
Perspective View Fig. 1.



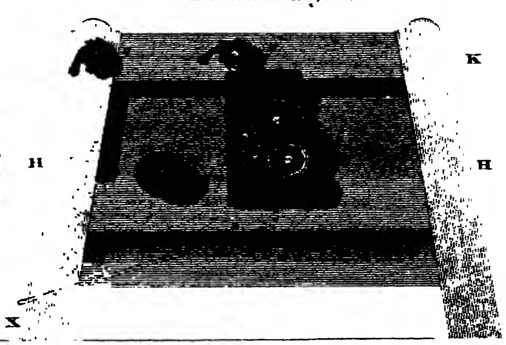
Section Fig. 2.



End View Fig. 3.



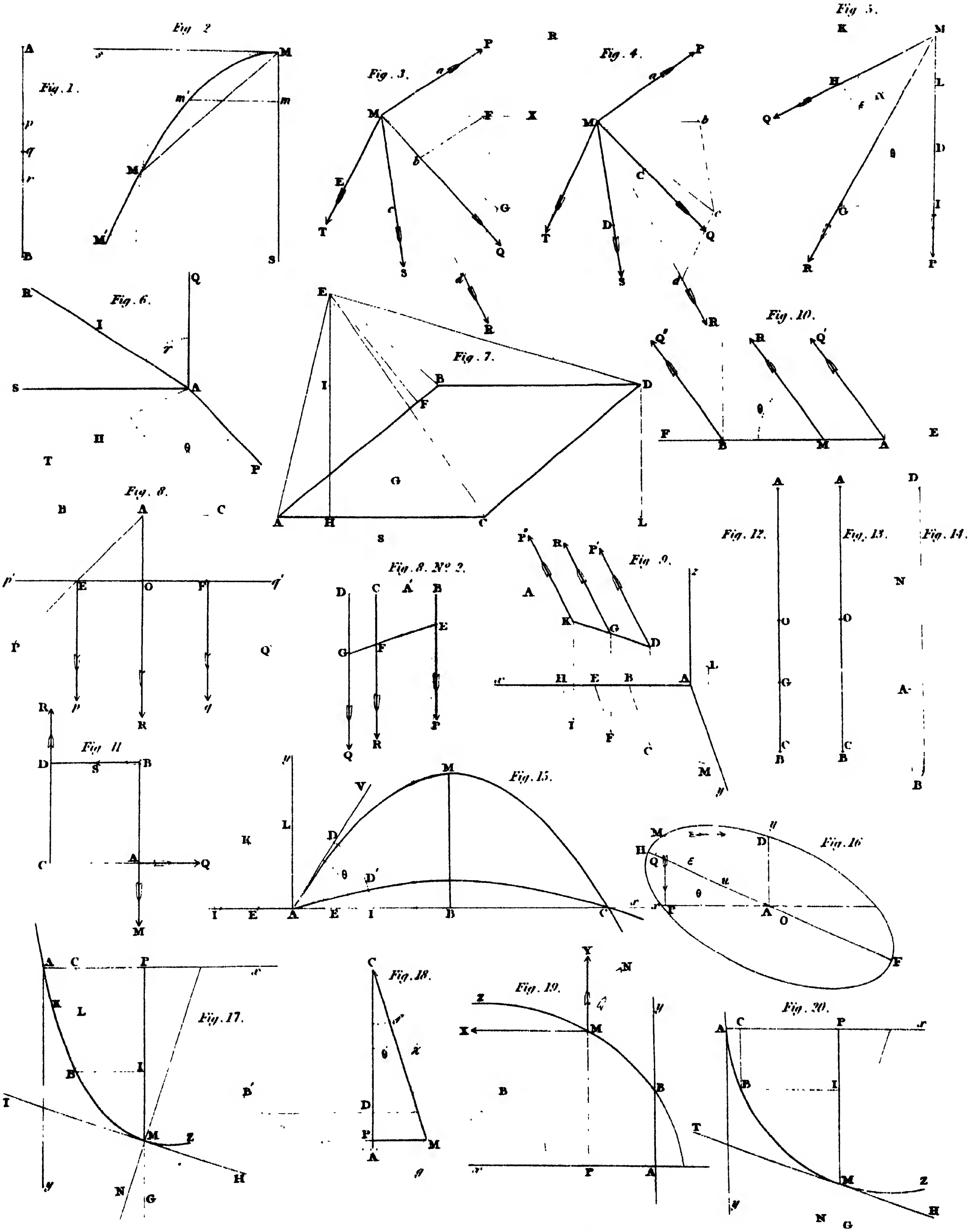
Elevation Fig. 4.



Published as the Act directs 1814 by Longman Hurst Rees Orme & Brown Paternoster Row, London.

Lowry sculp.

FORCE.



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Lowry sc.

FRICTION AND FULLING MILL.

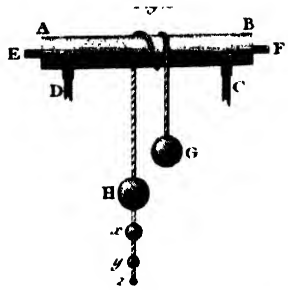


Fig. 2.

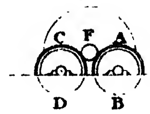
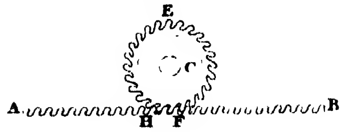
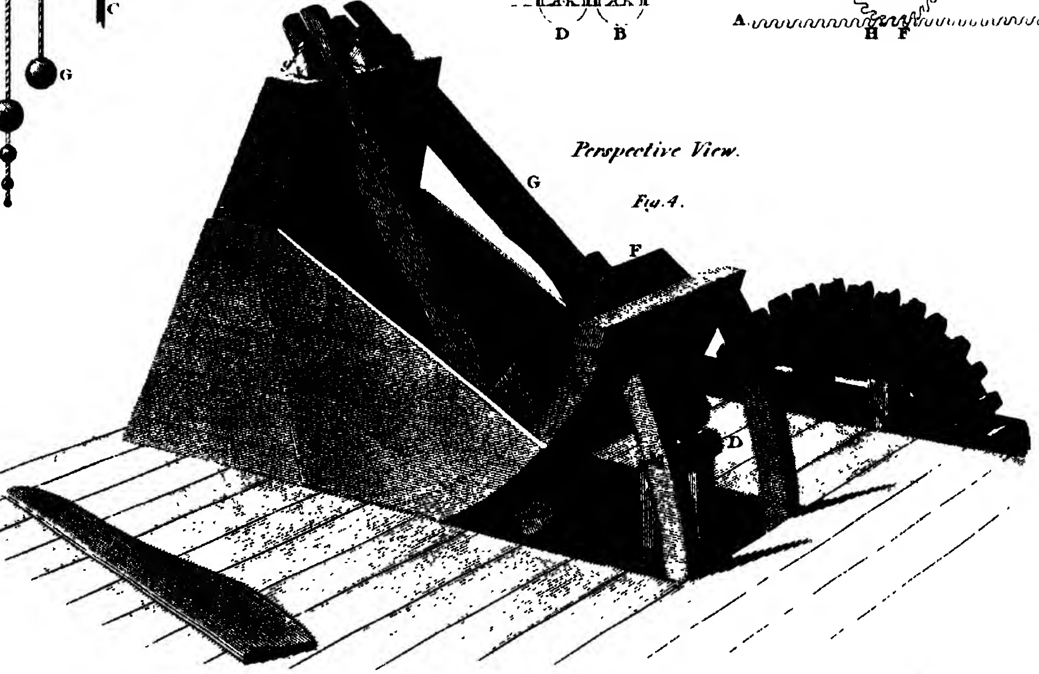


Fig. 1.



Perspective View.

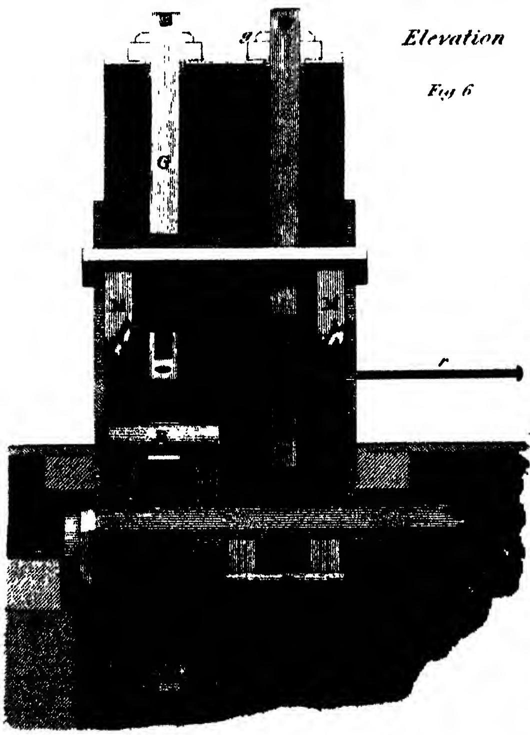
Fig. 4.



Note, these Stocks are for Scouring; for Milling cloth the trough a a is differently formed, see Woollen

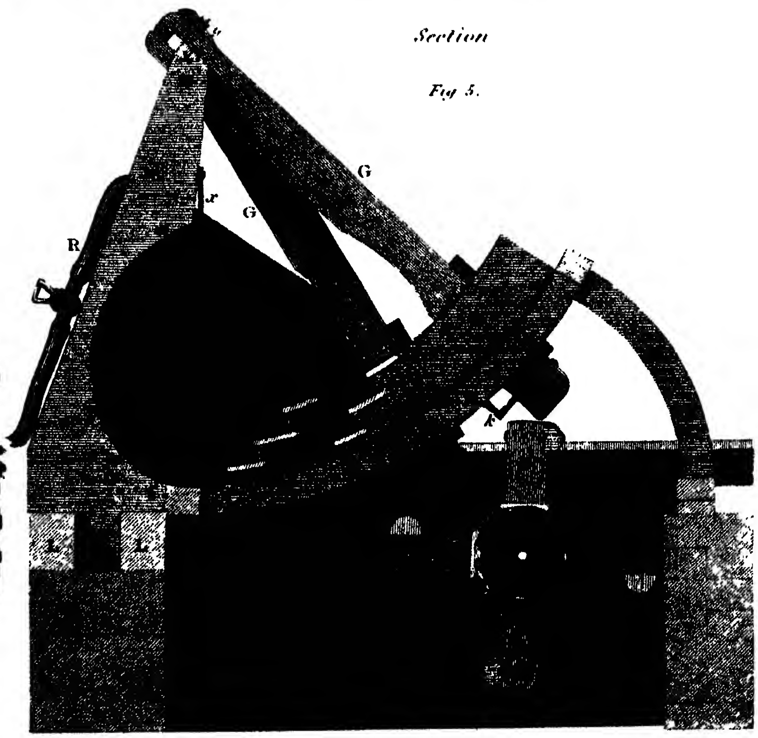
Elevation

Fig. 6.



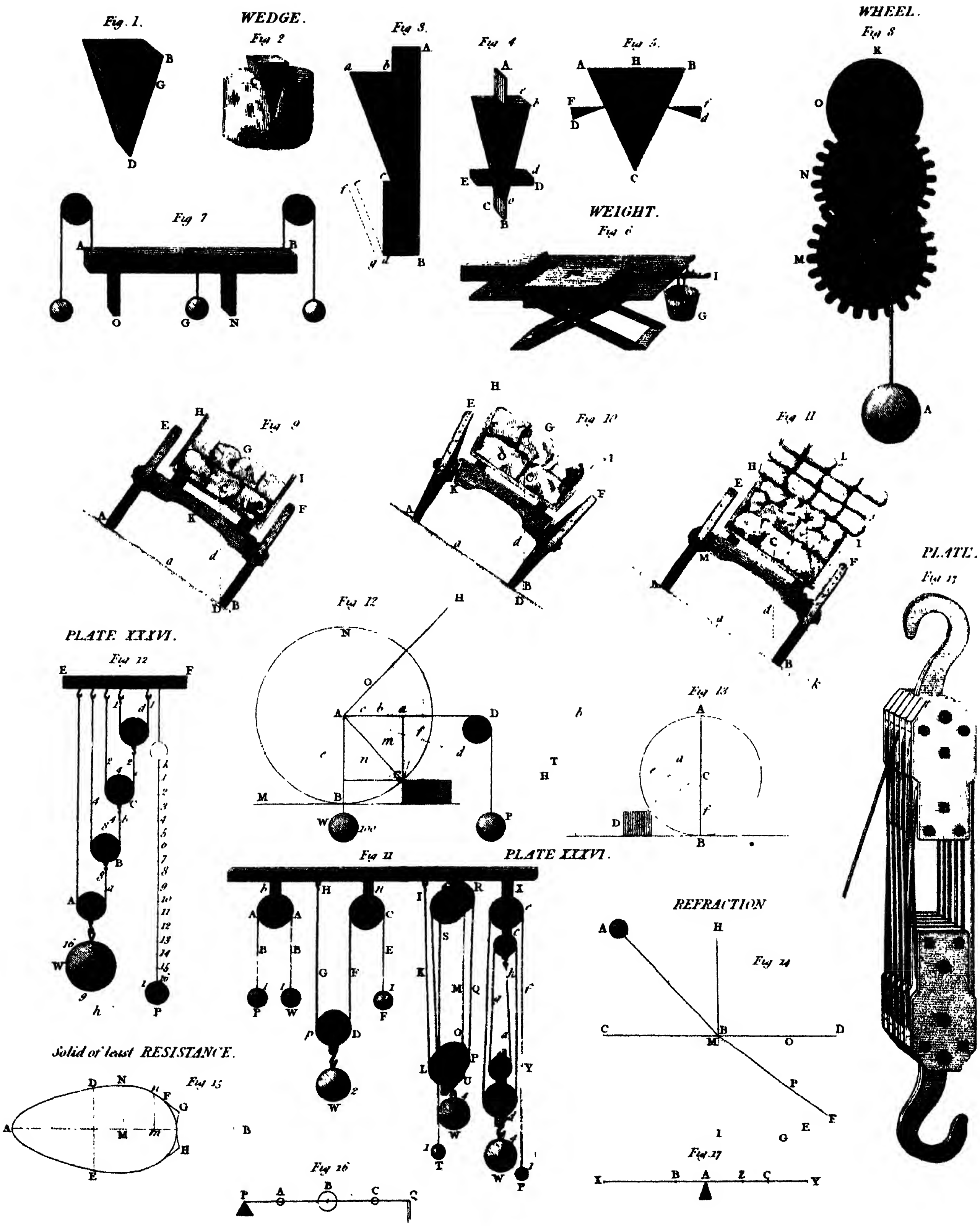
Section

Fig. 5.



J. Farey Junr. del. Published as the Act directs, 1817, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row. Lowry Sc.

MECHANICS



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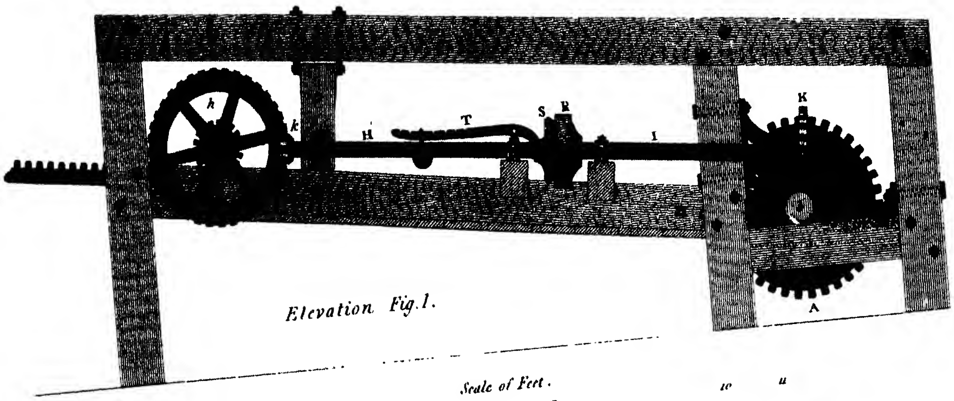
Lowry Sc.

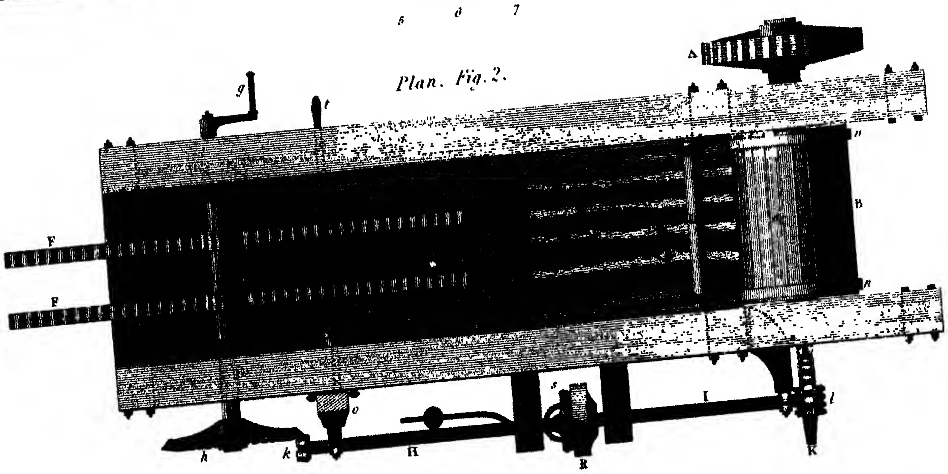
MECHANICS.

LOG-WOOD MILL.



Elevation Fig. 1.

Scale of Feet.



Plan. Fig. 2.

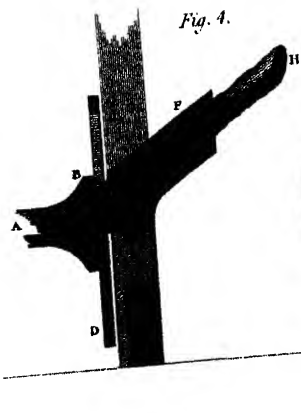


Fig. 4.

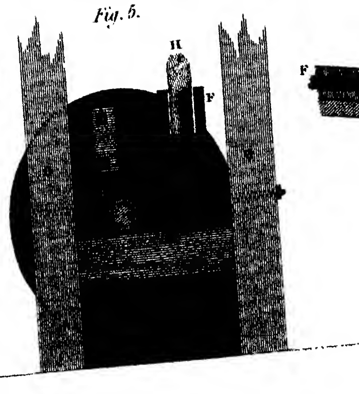


Fig. 5.

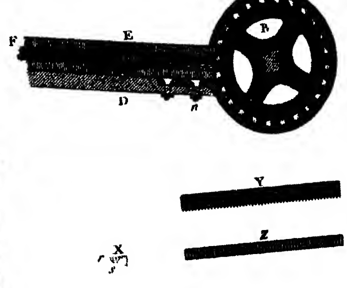


Fig. 3.

Lowry sculp.

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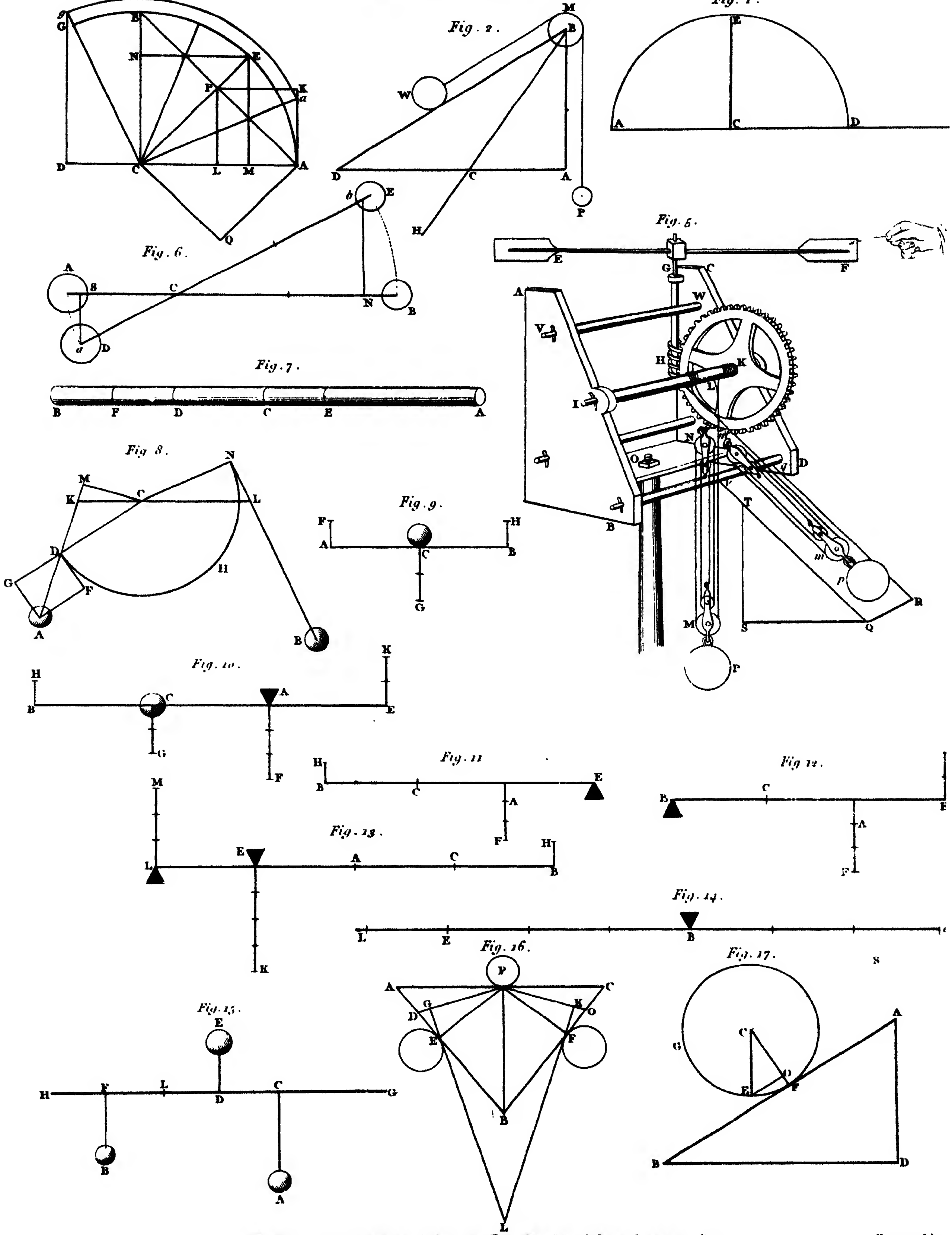
MECHANICS

MECHANICAL POWERS &c.



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Engraved by

Fig. 1.

View of a Common Breast Mill.

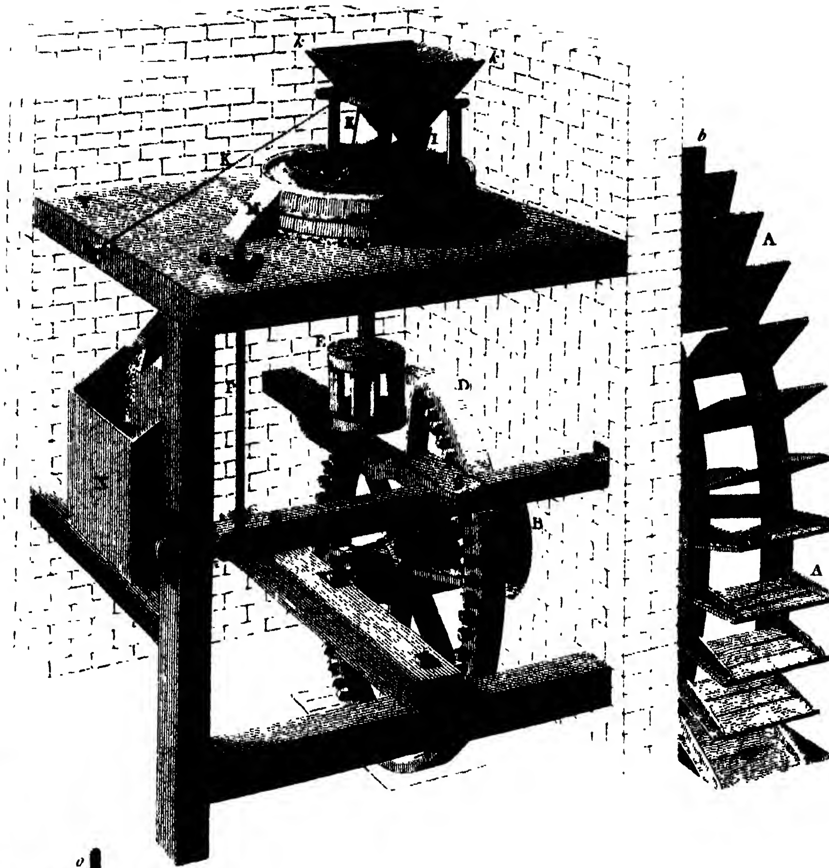
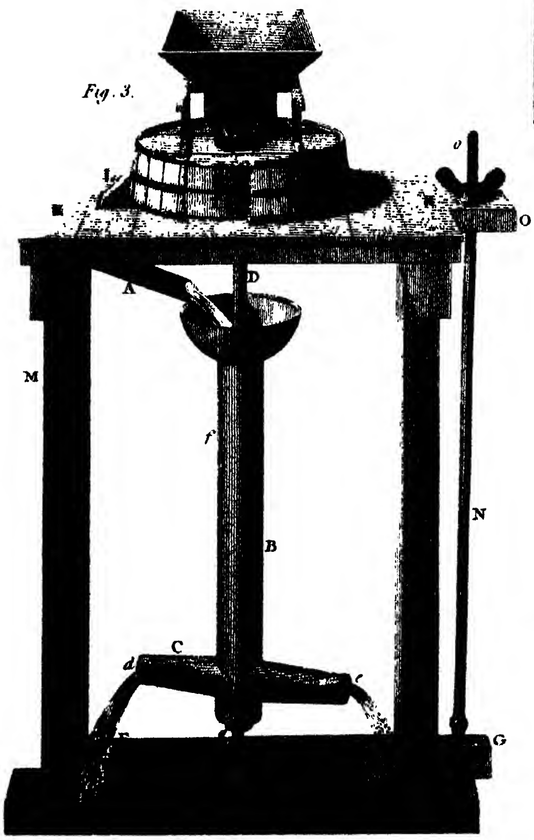


Fig. 2.

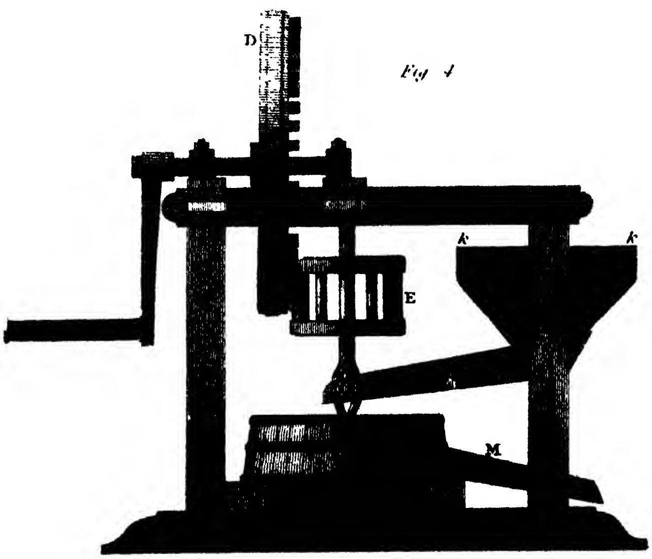
Dr Barker's Mill.

Fig. 3.



Portative or Hand Mill

Fig. 4.



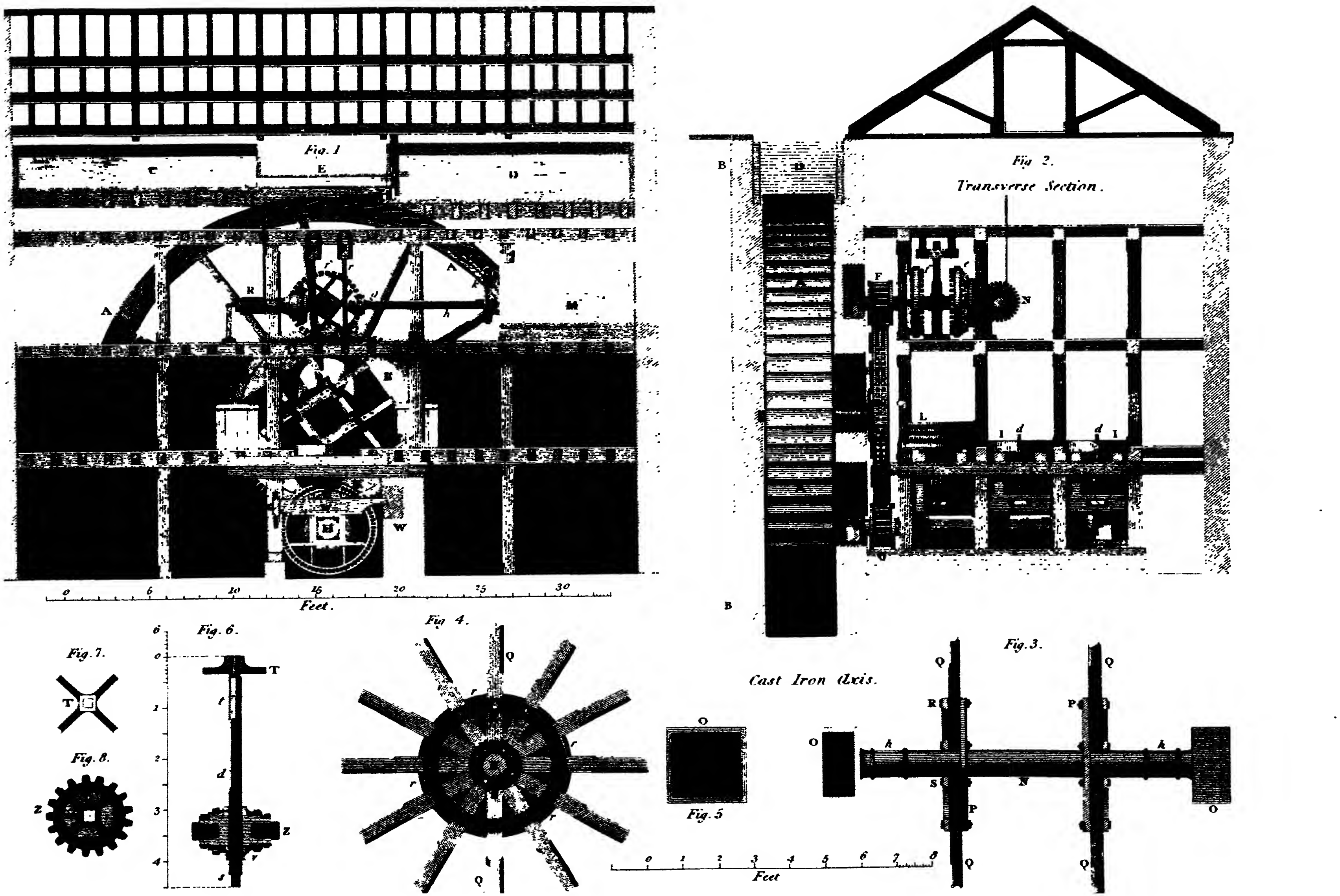
Farey. delin.

Published as the Act directs. [illegible], by Longman Hurst, Rees Orme & Brown, Paternoster Row.

Lowry. sculp.

FLOUR MILL.

Designed by J. SMEATON, F. R. S. 1781.



MECHANICS.

PLATE XXXIV.

MOTION. &c.

Fig. 1.

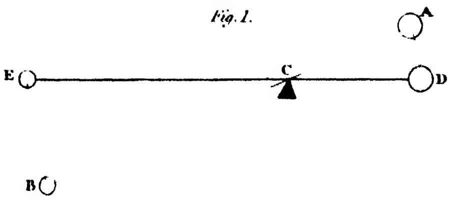


Fig. 2.

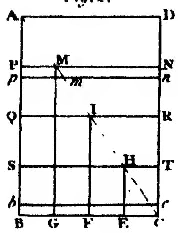


Fig. 3.

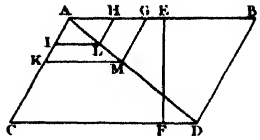


Fig. 4.

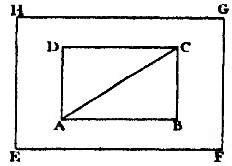


Fig. 5.

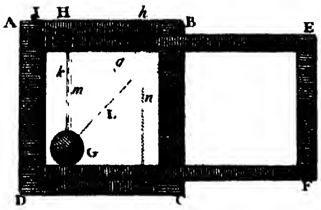


Fig. 6.

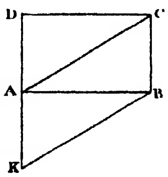


Fig. 7.

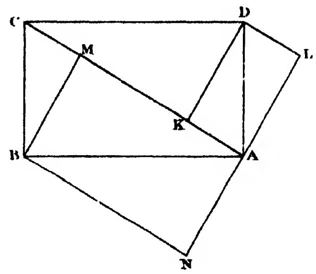


Fig. 8.

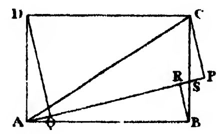


Fig. 9.

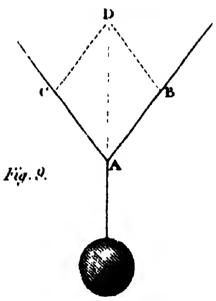
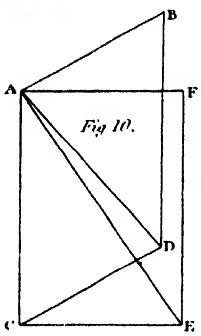
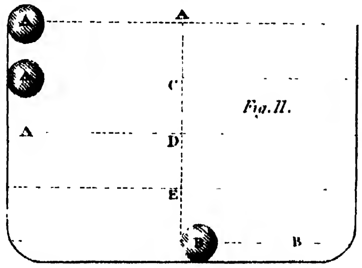


Fig. 10.



Perpetual MOTION

Fig. 11.



PERCUSSION

Fig. 12.

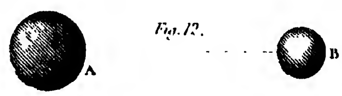
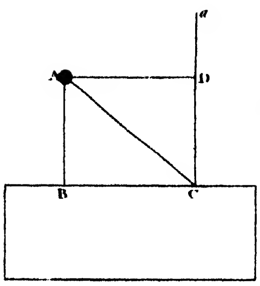


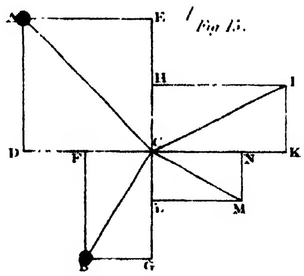
Fig. 13.



PERCUSSION

Fig. 14.

Fig. 15.



Inclined PLANE.

Fig. 16.

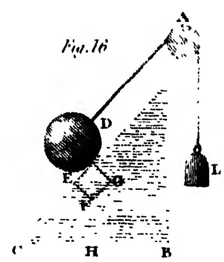


Fig. 17.

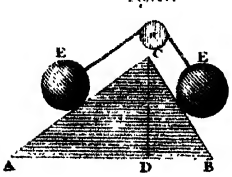


Fig. 18.

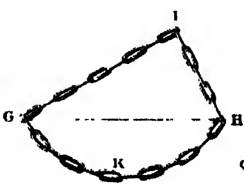


Fig. 19.

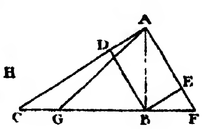


Fig. 20.

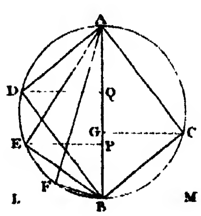
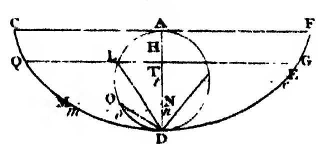


Fig. 21.



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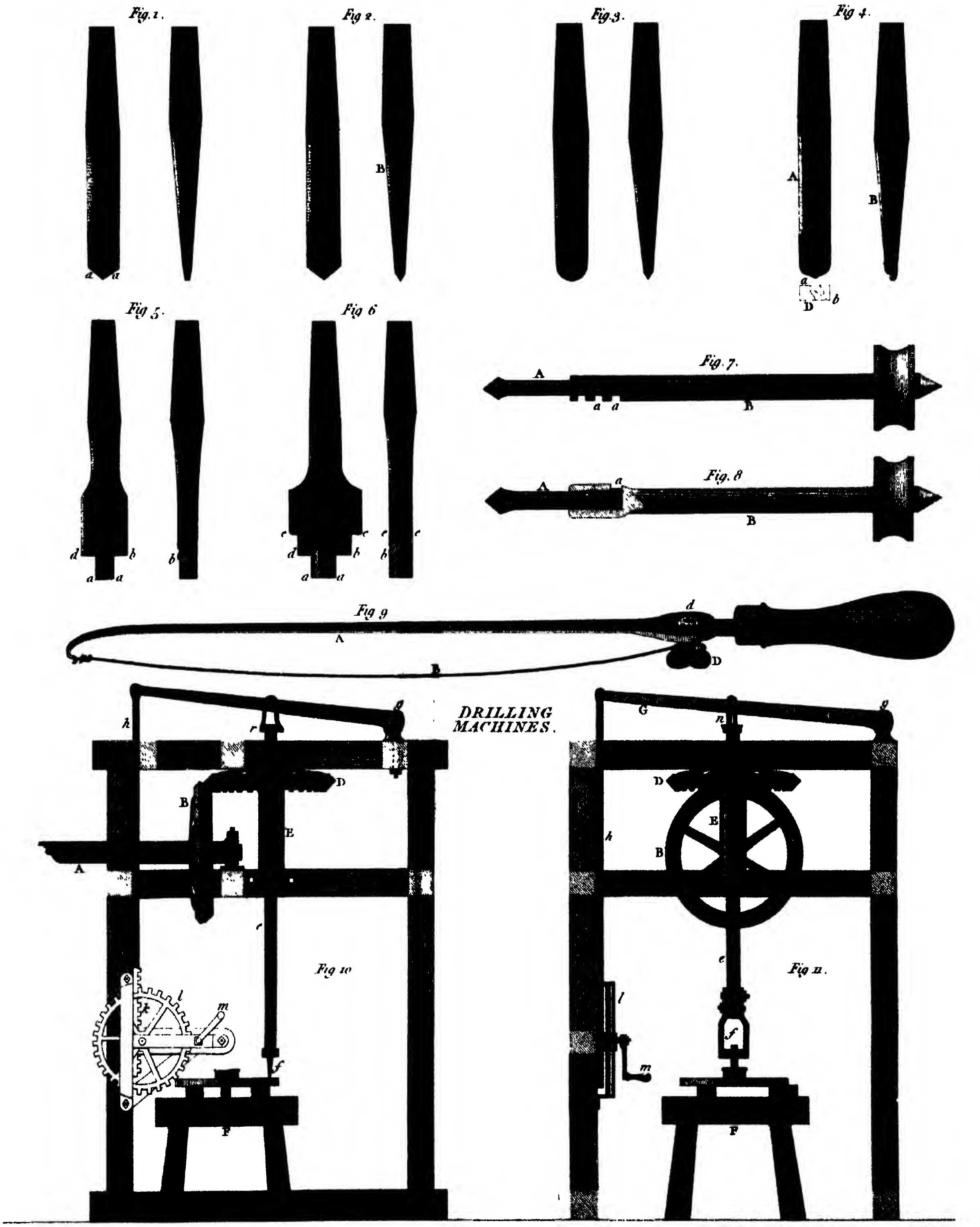
MECHANICS.

PLATE

DRILLS.



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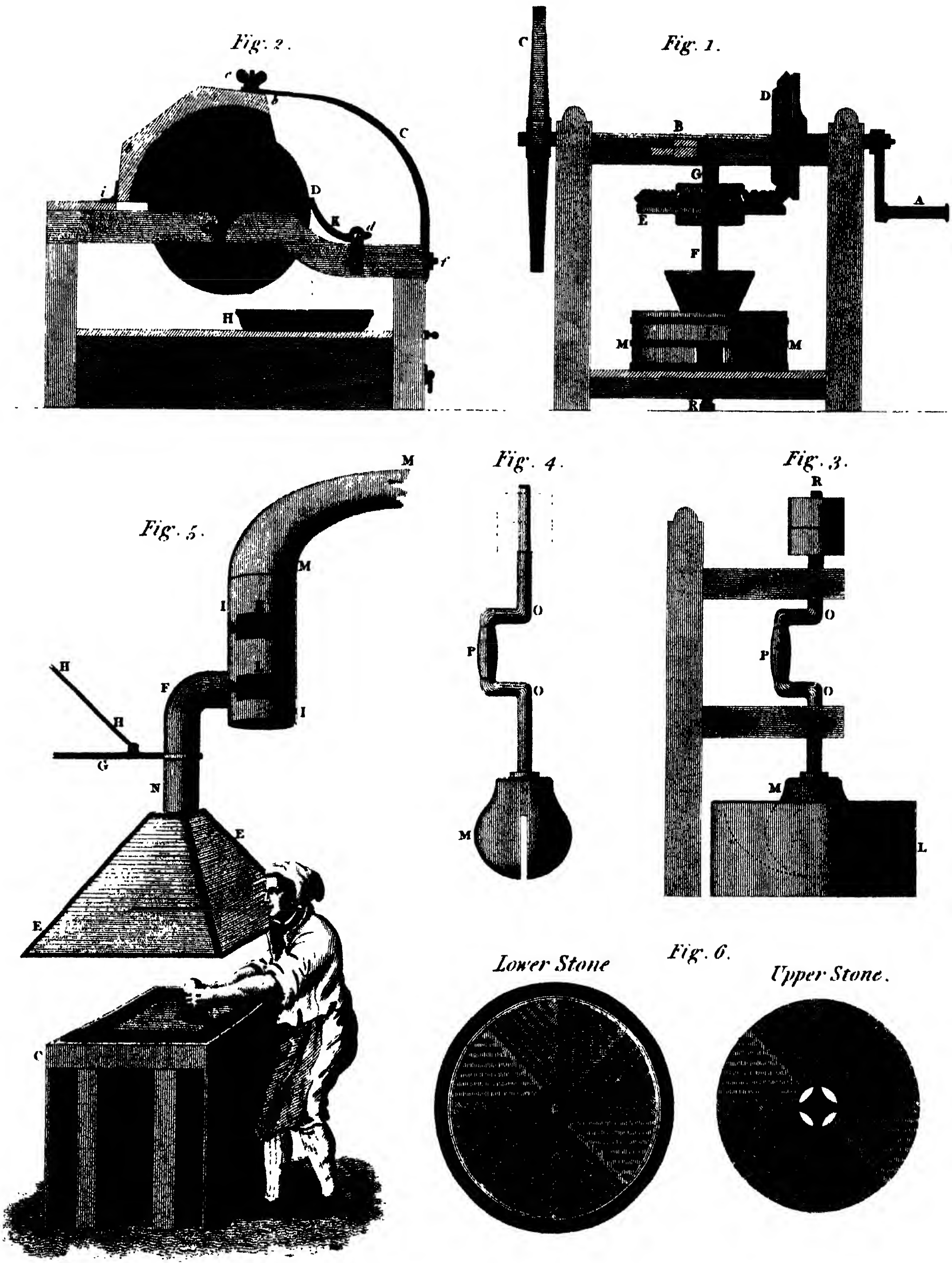
MECHANICS

COLOUR MILL.



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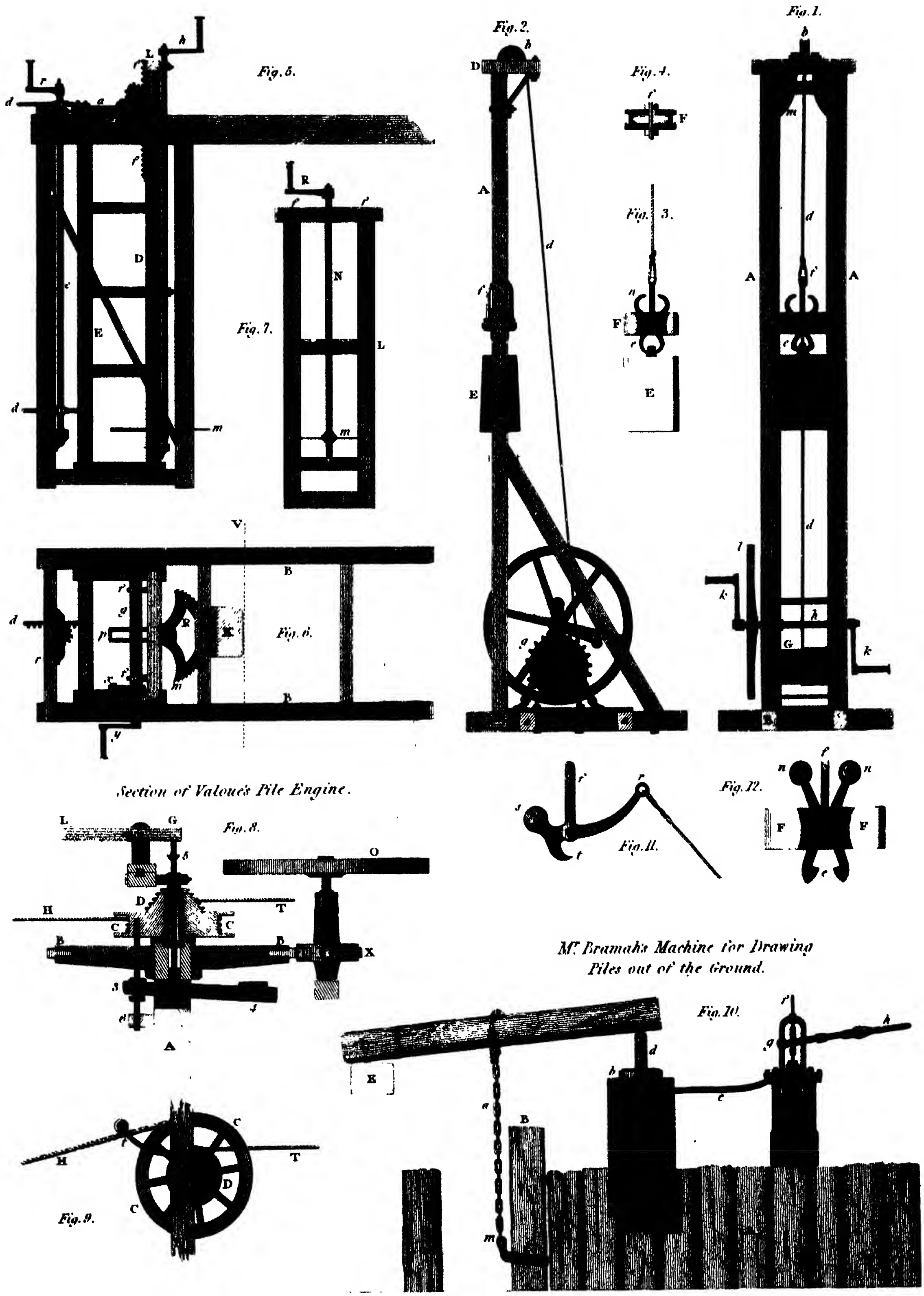
MECHANICS.

PILE DRIVING MACHINE.



J. Farey del.

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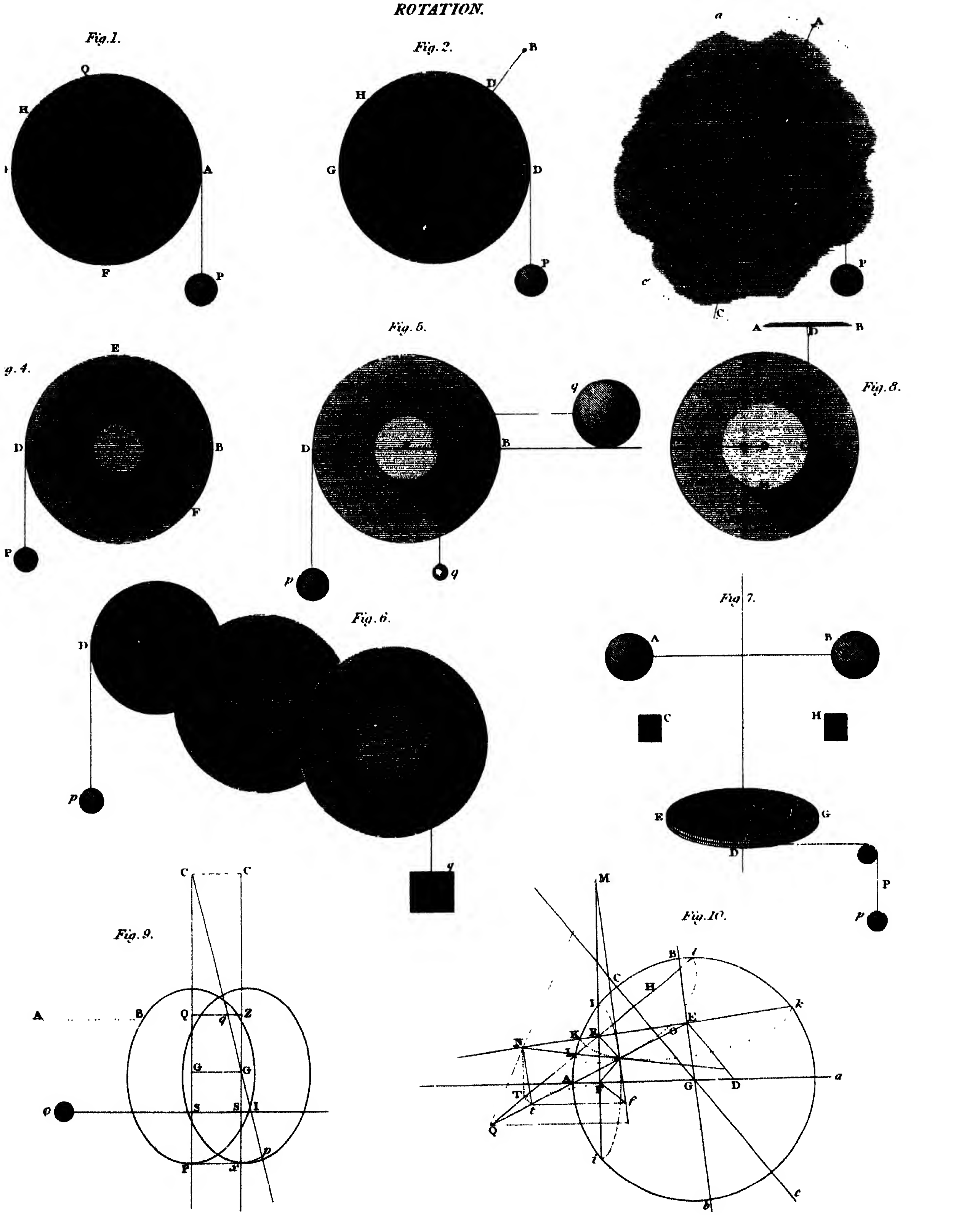
Lowry sculp.

MECHANICS.

ROTATION.



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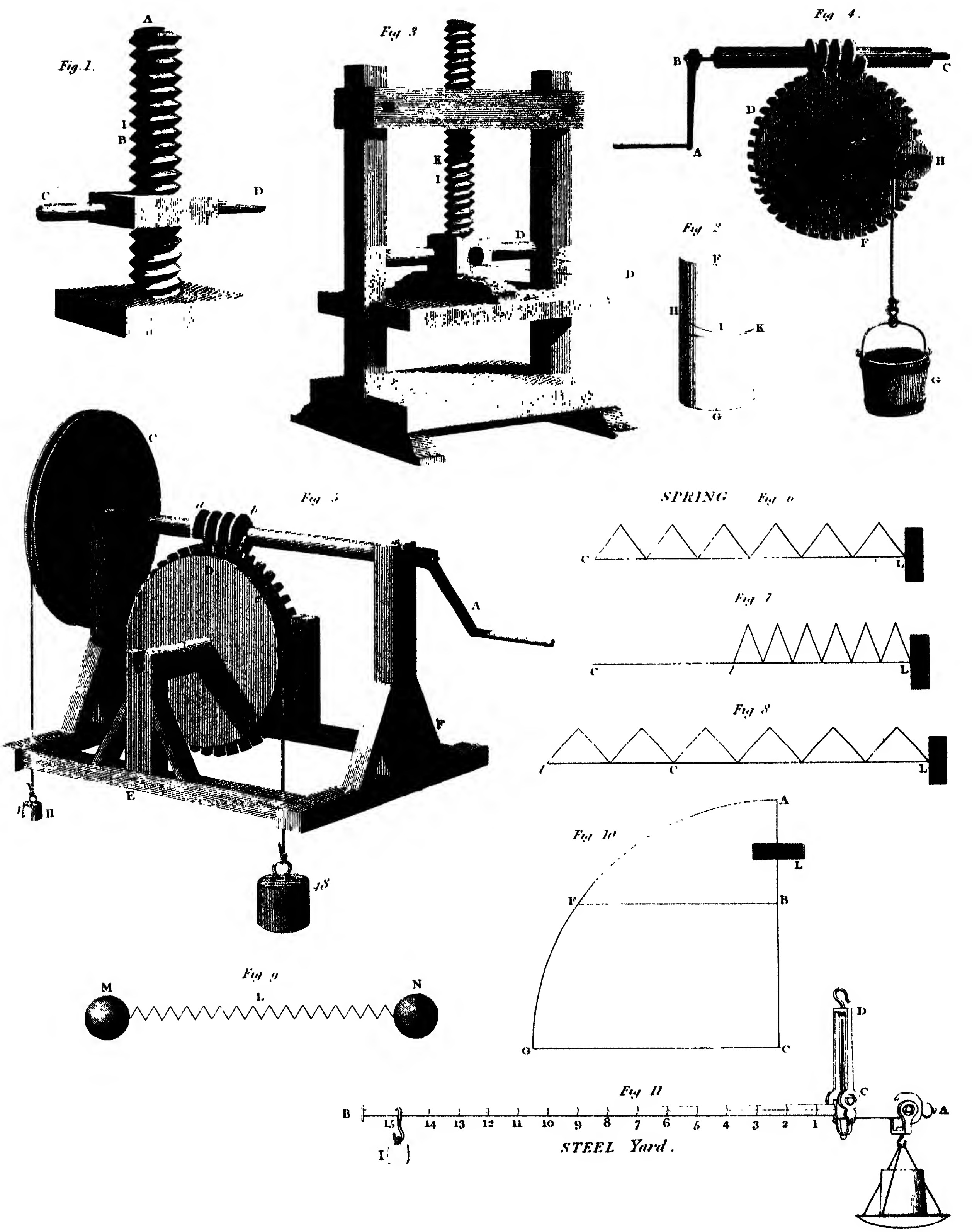
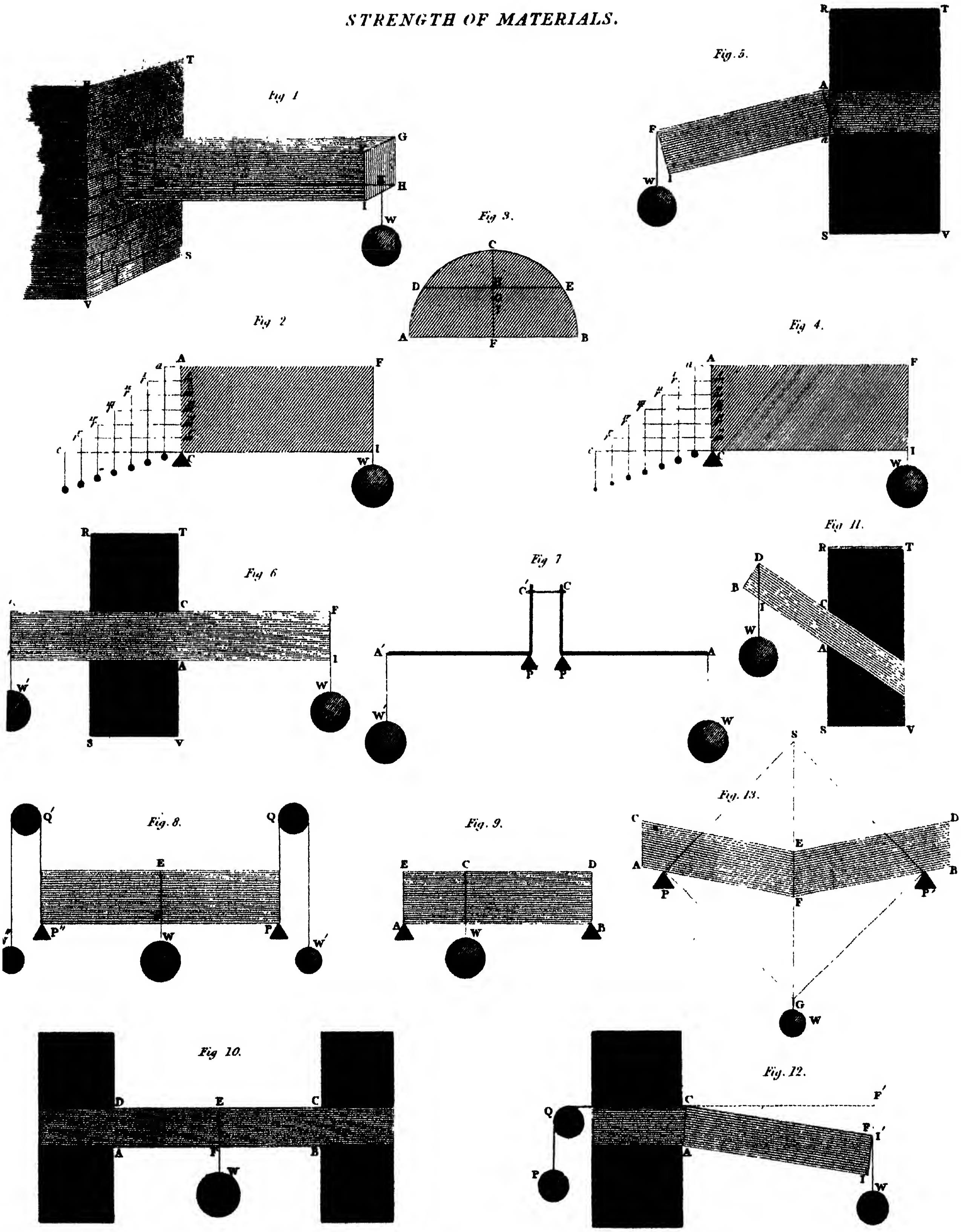
Lowry sculp.



Published as the Act directs, 1820, by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

Lowry, sc.

STRENGTH OF MATERIALS.



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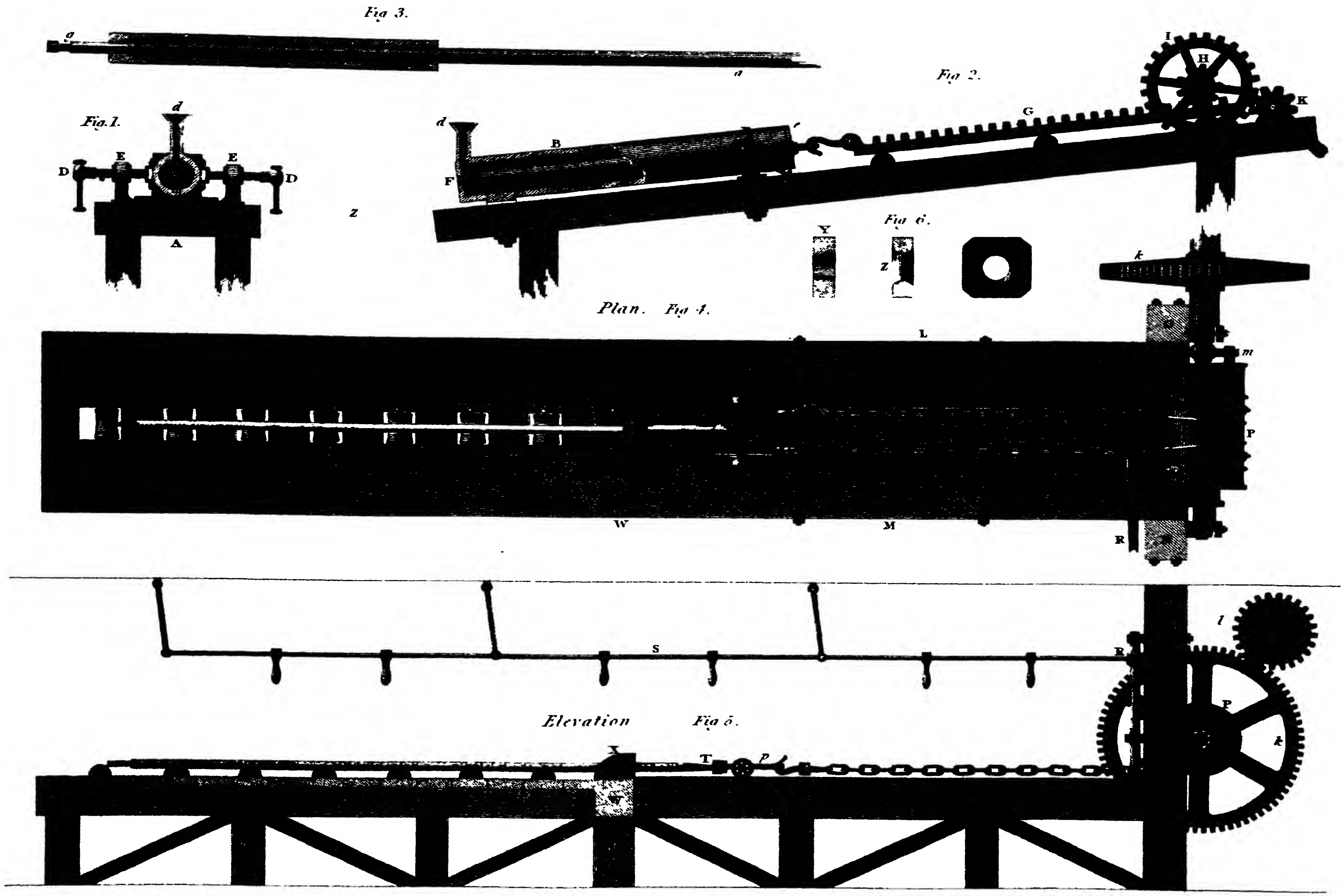
MECHANICS.

Machines for casting and Drawing Lead Pipes



Melting-cone

MELTING-Cone, in *Assaying*, is a small vessel made of copper or brass, of a conic figure, and of a nicely polished surface within. Its use is to receive melted metals, and serve for their precipitation, which is effected, when two bodies melted together, and yet not mixing perfectly with one another in the fusion, separate in the cooling into two strata, on account of their different specific gravity. This precipitation might be made in the same vessel in which the fusion is performed; but then the melting-pot or crucible must be broken every time to get it out, whereas the conic shape, and polished surface of this vessel, makes it easily got out without violence. The shape of this vessel is also of another use in the operation; for by means of it, the heavy matter subsiding to a point, is formed into a perfect and separate regulus, even where the whole quantity, as is very frequently the case, has been but very small.

When the quantity of the melted matter is great, it is common to use, instead of this cone, a large brass or iron mortar, or any other conveniently shaped brass or iron vessel. It is necessary, when the cone is of brass, to be cautious that it be not made too hot; for the brittleness of that metal, when hot, makes it easily break, on the striking with any force on that occasion, to make the melted mass fall out.

These, and all other moulds for the receiving melted metals, must always be well heated before the mass is poured into them, lest they should have contracted a moisture from the air, or have been wetted by accident; in which case the melted metal will be thrown out of them with great violence and danger. They ought also to be smeared over with tallow on their inside, that the regulus may be the more easily taken out of them, and the surface of the mould not corroded by the melted mass poured in.

If a very large quantity of a metal is, however, to be received into them, and especially if any thing sulphureous have place among it, this caution of tallowing the moulds does not prove sufficient; for the large quantity of the mass makes it continue hot so long, that this becomes but a slight defence to the surface of the mould. In this case the assayer has recourse to a lute, reduced to a thin pap with water, which being applied in form of a very thin crust, all over the inside of the cone, or mould, soon dries up, indeed, but always preserves the sides of the vessel from the corrosion of the mass. And this caution is found necessary, even when pure copper is melted alone, without any mixture of sulphur.

Merthyr Tydfil

MERTHYR TYDVIL, or *Tudfyl*, in *Geography*, a large and populous market-town, situated in the cwmwd of Senghenydd, cantref of Brenhinol, now the hundred of Caerphilly, and county of Glamorgan, South Wales. It is a place of great antiquity, and is said to derive its name from Tydvil, the daughter of Brechan, prince of Brecknockshire, who was murdered here, along with her father and brother, Rhun Dremrudd, by a party of Saxon marauders, about the close of the fifth century. Tydvil was the wife of Cyngin, son of Cadell, prince of the vale royal and part of Powys, and is reckoned among the number of the ancient British saints. After her death, the Saxons having been expelled by the prowess of her nephew, Nevydd, a church was erected and dedicated to her at this place, and called the church of Merthyr Tydvil, which in Welsh signifies "the Martyr Tydvil."

From this period, nothing occurs deserving of notice relative to Merthyr Tydvil, till about the year 1620, when it was distinguished for its zeal in the cause of non-conformity. Though then trivial in extent and political importance, it was nevertheless a sort of hot-bed, which contributed in no small degree to engender and keep alive, for more than a century, those religious dissentions, the effects of which still continue visible in the separation of the greater proportion of the inhabitants of Wales from the established church. In 1755 a new era commenced in the history of this place. The extensive and valuable mines in its immediate vicinity had hitherto attracted but little notice. At this time, however, Mr. Bacon particularly directed his attention towards them; and having obtained a lease of a district, extending about eight miles in length, and four in breadth, at the moderate rent of 200*l.* *per annum*, immediately began operations, and erected extensive works for the smelting and forging of iron. This gentleman continued increasing his establishment till the year 1783, when he deemed it proper to let out the greater part of his property to Mr. Crawshay, and the remainder to Mr. Hill: at the same time, he reserved to himself a certain tonnage on all the iron manufactured above a specified quantity. The new proprietors soon augmented the works; and the part belonging to Mr. Crawshay, at Cyfartha, are now by far the largest in this kingdom, and probably in Europe. He employs no fewer than 1500 men, at an average of 30 shillings a week *per* man. The weekly wages paid for labour amount to 1500 pounds.

The average of iron produced from these works is from 180 to 200 tons a week. Six furnaces and two rolling-mills are employed. For procuring blast for the furnaces and working the mills, there are four steam-engines; one of fifty, one of forty, one of twelve, and one of seven horse power. The first engine is connected with the four upper blast-furnaces, to which is a water-engine annexed of nearly the same power. The machinery of this establishment is truly gigantic; and that part of it worked by water is curious, and certainly highly powerful. The great water-wheel is a most extraordinary piece of mechanism: it was constructed under the superintendance of Watkin George, and measures 50 feet in diameter. W. George was then a carpenter employed about the works: he was afterwards taken into partnership, and received 20,000*l*. to give up his share. Besides these works, and those of Mr. Hill, there are two others at Pendarren and Dowlais; the former producing about 140 tons of iron weekly, and the latter about three fourth-parts of that quantity. The total number of smelting-furnaces near this town is seventeen, *viz*. Dowlais four, Pendarren three, Plymouth (Mr. Hill) four, and Cyfartha six.

No fact can better illustrate the magic influence of trade on the condition of a country, than the rapid change which has been effected at Merthyr Tydvil and its neighbourhood. Forty years ago, this town was an inconsiderable village, and contained only a few hundred inhabitants; whereas, by the sole operation of its iron-works, it has risen to be by far the largest and most populous town in Wales. The inhabitants of this parish were estimated at 7705, in 1801; but the population is conjectured to amount to 10,000 persons. In 1803 the money raised for the poor rates, at 6*s*. 6*d*. in the pound, was 1453*l*. 17*s*. 10½*d*. The streets in general are close and confined, and have no proper outlets behind the houses. Considerable improvements, however, have already been made within these last five or six years. Such streets as have been built since that period are much better arranged, and wider than those which were erected earlier. At Pendarren is a large and elegant house, surrounded by beautiful gardens and pleasure-grounds, belonging to Mr. Homfray. The parish church, rebuilt in 1806, is a large and handsome building; and besides it, there is a spacious chapel built by Mr. Crawshay. The meeting-houses for dissenters of different sects are about eleven in number: three Baptists, two Presbyterian, two Independents, two in the Wesley connection, and two in that of Whitfield. A theatre has been lately erected here. There is likewise a philosophical society here, as well as a printing-house, and a book-seller. The inhabitants of this town are chiefly Welsh, and the language spoken in it almost entirely so. Less immorality prevails than might be expected in a place where the population consists chiefly of the lower orders. This is partly owing to the circumstance of the iron-masters and clergymen being usually magistrates for the county, and partly to the effect of religious instruction. These magistrates have the power of nominating the requisite number of constables, and must submit all their proceedings to the quarter and great sessions. A court of conscience, for the recovery of small debts, has been instituted here by act of parliament, within these three years. This town has three market-places, which are well supplied twice every week, on Wednesdays and Saturdays. It has likewise several fairs during the year.

The weighty and valuable productions of Merthyr Tydvil find an easy conveyance to the sea, by means of a canal which extends hence to Penarth harbour, in the Bristol channel, being navigable as far as Cardiff for vessels of 300 tons, and above that town for barges of 100 tons. This canal, begun about 22 years ago, was completed in 1798. At the Cyfartha works, where it terminates, it is 568 feet above the level of the sea; which elevation is effected by means of about 40 locks. A new tram road runs nearly by its side, through its whole course, extending altogether 26 miles in length.

Besides its iron ores, the neighbourhood of this town is abundantly productive of other minerals useful in the arts, and consequently subservient to the convenience and happiness of man. Coal, so indispensibly necessary in the manufacture of the iron, is supplied in immense quantities, and of excellent quality. Good mill-stones and stones for paving are likewise abundant; and in the lime-stone rocks are found beds of black and variegated marble, not inferior to any in the kingdom.

About two miles from the town, on the summit of a lofty mountain, is situated a very ancient market-place, where weekly markets have now been held for upwards of 800 years, during the summer season, from the 14th of May till the 14th October. This singular market is still much frequented. Several fairs are likewise held here for cattle, though the houses in the place do not exceed six in number.

Morlais castle stands about three miles to the north-west. It is situated on the summit of a hill, about half a mile from the ancient road over the mountains from Cardiff to Brecknock, overlooking a ravine of great depth, in the bottom of which runs a branch of Taff Vechan river. The area of this castle forms an irregular pentagon, defended on the south and east sides by a very large and deep trench cut in the solid rock. On the north and west sides it is rendered sufficiently strong, by the bold and rugged precipices which overhang the dingle. The whole of this castle is now in ruins. It was built by Ivor Petit, or Ivor Bach, the son of Cedevor, who was no less distinguished for his valour than for the uncommon smallness of his stature. Malkin's Scenery, Antiquities, and Biography of South Wales, 2 vols. 8vo. 1807. Carlisle's Topographical Dictionary of Wales, 1 vol. 4to. 1811.

Metals

METALS, in *Chemiſtry*, a claſs of ſimple bodies poſſeſſing peculiar properties. The ancients, who valued theſe bodies moſt for their phyſical properties, did not beſtow the excluſive name of metal on any body which was not malleable. Other bodies, which poſſeſſed ſimilar characters, without being malleable, were called ſemi-metals. The peculiar brilliancy belonging to the metals is perhaps their moſt generally diſtinguiſhing character. The luſtre exhibited by mica has ſome reſemblance to the luſtre of metals, but it is very inferior in degree, and is merely confined to the ſurface. The great ſpecific gravity of moſt metals has been thought a ſufficiently diſtinguiſhing character. This property, to a certain extent, was very ſtriking. Till the late diſcoveries of Mr. (ſir H.) Davy, the lighteſt of the known metals was of greater ſpecific gravity than the denſeſt body which was not a metal. The baſes of potaſh and ſoda, however, have all the characters of metals, with the exception of being defective in the property juſt alluded to, ſince potaſſium and ſodium are of leſs ſpecific gravity than water. From theſe facts, therefore, we are no longer allowed to ſay that all metals are of greater ſpecific gravity than other bodies.

In the preſent ſtate of our knowledge there appear to be two claſſes of elementary matter, namely, oxygen, which conſtitutes one claſs, and oxydable bodies, or ſuch bodies as combine with oxygen. Of the latter claſs, out of 45 varieties, there appear to be only five which are not metallic. The metals, therefore, compriſe by far the greateſt part of the elementary bodies.

Dr. Thomſon has divided the metals into four claſſes: 1. Malleable. 2. Brittle and eaſily fuſed. 3. Brittle, and difficultly fuſed. 4. Refractory.

I. Malleable.

Gold.	8. Mercury.
Platinum.	9. Copper.
Silver.	10. Iron.
Palladium	11. Lead.
Rhodium.	12 Tin.
Iridium.	13. Nickel.
Oſmium.	14. Zinc.

II. Brittle, and eaſily fuſible.

1. Biſmuth.	3. Tellurium.
2. Antimony.	4. Arſenic.

III. Brittle, and difficultly fuſible.

1. Cobalt.	4. Molybdenum.
2. Manganeſe.	5. Uranium.
3. Chronium.	6. Tungſten.

IV. Refractory.

1. Titanium.	3. Cerium.
2. Columbium.	

Beſides the metals arranged in this table, there are a number of others lately diſcovered by Mr. Davy, which are the baſes of ſome of the earths, and the two fixed alkalies. If the whole of the earths, as well as the two fixed alkalies, have metallic baſes, the number of metals to be added to the above will be 13. Thoſe from potaſh, ſoda, barytes, ſtrontian, zinc, and magneſia, have already been obtained, and have been named by Mr. Davy, potaſſium, ſodium, barium, ſtrontium, calcium, and magneſium. The four firſt of theſe appear to be malleable metals; the others are not ſufficiently known.

Thoſe metals which are not liable to be oxydated by expoſure to the air, ſuch as gold, platina, ſilver, &c. have been called noble; while thoſe which become tarniſhed and corroded, were termed baſe metals. Theſe diſtinctions have now become obſolete.

The metals have always, and muſt continue to be of the utmoſt importance in chemiſtry, in the arts and manufactures, and in domeſtic economy. Their malleability and hardneſs render them highly fitted for making various veſſels and utenſils, and their luſtre and colour are agreeable to the eye. The properties of hardneſs and tenacity united. ſuch as belong to iron and ſteel, are of great utility in various kinds of edge-tools, and the elaſticity which is conſtituted by certain degrees of theſe two properties, could ſcarcely be furniſhed by any other ſubſtance than ſteel; hence its great uſefulneſs for making ſprings.

The ductility of ſome metals is ſo great, as to admit of its being drawn into wires much finer than a hair. Gold, although the moſt laminable of all the metals, or which may be made into the thinneſt leaves, does not admit of being drawn into the ſmalleſt wire, owing to its want of hardneſs. Iron, in conſequence of poſſeſſing greater hardneſs, with a conſiderable portion of that property by which the particles of bodies attract each other in all ſituations equally, is capable of being drawn into finer wire than gold. Indeed pure gold is leſs ductile than when it contains a certain portion of copper. In treating of ſome of the phyſical properties of metals, ſuch as malleability, ductility, hardneſs, and tenacity, much uncertainty has prevailed, from the want of ſome of theſe terms having definite meanings.

That property of a metallic bar or wire, by which it reſiſts the action of a weight in the direction of its length, has been called tenacity, and this is always the meaſure of its ſtrength. This power in metals, however, is evidently dependent upon two properties, one of which is its hardneſs, and the other a property for which philoſophers have no preciſe word; perhaps the word flexibility may come the neareſt. We mean, however, that property by which its particles can be changed into any ſituation, without ſeparation. In the drawing of a piece of wire, ſome of thoſe particles which conſtitute its thickneſs, before it paſſes through the hole of the wire-plate, are, by the proceſs of drawing, brought into the direction of its length. This property in the greateſt degree enables a piece of wire, or a thin ſlip of metal, to be bent backwards and forwards without breaking. A ſingle experiment will ſatisfy any one of the propriety of theſe remarks. Take a piece of copper or iron wire, previouſly well annealed, and it will be found exceedingly flexible, and may be twiſted or bent conſiderably, without breaking. If a weight be hung to it, with a view to break it, it will ſtretch conſiderably before it breaks. If a piece of the ſame wire be drawn through one or two holes, it will be found much ſtiffer and harder, and of courſe ſmaller: it will alſo be leſs capable of being bent or twiſted without breaking. If, however, a trial be made of its ſtrength, it will require a much greater weight to break it than in the annealed ſtate; although its diameter is diminiſhed. If the hardneſs be ſtill increaſed by theſe means, a maximum of ſtrength would be found under ſome joint proportion of the hardneſs, and the property of bending or twiſting, which we may for the preſent call flexibility. It is on this latter property, with a certain degree of hardneſs, that the malleability and ductility of metals depend. It requires rather leſs hardneſs to make a metal to the beſt advantage into ſheets, than to draw it into wire. This evil, however, of the wire breaking from being ſoft, may be remedied by making leſs difference in the ſize of the holes in the wire-plate. By this means the greateſt ductility and malleability may exiſt under the ſame degrees of hardneſs and flexibility.

Metals, with regard to their hardness and flexibility, are very different under different circumstances. Some metals, however, are more susceptible of this change than others. Steel may be so soft and flexible as to bear much twisting, and be easily penetrable by the file, which happens when it is newly annealed; while, if it is heated red-hot, and cooled rapidly, it becomes extremely brittle, and is sufficiently hard to cut glass. Lead, on the contrary, under all circumstances, has the same degree of stiffness and hardness. The same is pretty nearly the case with tin.

Some hints were given under the article LIQUIDITY, which may throw some light on this mysterious property of metals. It is there conjectured, that the particles of bodies may be capable of assuming two states, one in which the particles attract each other equally in all directions. Hence whatever motion may take place among them, the same attraction still exists It is in this state that bodies can be changed in their figure, without destroying their aggregation.

On the other hand, it is supposed that the particles of bodies, under certain circumstances, may possess polarity; and that the strongest attraction, and, consequently, their greatest hardness, may exist, when the particles are so arranged that opposite poles are presented to each other. Any thing, therefore, which facilitates this change to polarity, will increase the hardness of a body. The crystalline form, which is common to some metals, strongly favours this idea; since metals are always harder in this state, than when their *fibrous form*, as it is called, is brought about. Metals seem to acquire the greatest hardness by cooling rapidly, through a great range of temperature. It is in this change, therefore, that the particles acquire the greatest polarity, and by which the body becomes the most brittle and elastic. Indeed it is on the principle of polarity only, that we are enabled to explain the elasticity of bodies. Heat appears to be the most efficacious in destroying the polar property. The body would, however, regain it by rapid cooling; but by slow cooling, it is rendered soft to the greatest degree of which it is capable, and in the same proportion malleable and inelastic.

The hardness of metals, when they have been annealed, may be considerably increased by hammering, rolling, or wire-drawing. This change appears to be brought about merely by condensation. The small degree of polarity left in the particles will exhibit itself in the elasticity, when the particles are brought nearer together. It will be equally evident that the particles will be attracted with more force, and that the hardness will be increased. The hammering does not appear to increase the hardness of a body which has assumed the crystalline form, under which the greatest polar power is supposed to exist, but rather to diminish it. If a piece of steel plate, which has been hardened and tempered, be hammered carefully, the elasticity and hardness become less. Upon heating it, however, till it becomes blue, the elasticity returns. The hammering, in this instance, deranges the poles of the particles, which the slight heat restores to their proper positions.

From what has been observed it will be easy to infer, that no metal can be malleable under its crystalline or polar form. Several of the metals are scarcely susceptible of this form: among these we may enumerate gold, silver, and lead, and, in all probability, mercury. Others are deprived of it, and become malleable by hammering or rolling at a certain temperature. Of these are copper, brass, iron, steel, tin, and zinc. There are other metals, indeed the greatest part of them, which are not capable of any other than the crystalline form, and hence are not malleable. Of these we may mention antimony, bismuth, arsenic, cobalt, and manganese. What strengthens the idea that the crystalline form is the cause of the want of softness and malleability, is the circumstance of copper and tin being separately very soft and malleable; though an alloy of these two metals is as hard as steel, and does not possess the least malleability. Cast steel and blistered steel are in the crystalline form, till they have been hammered at a certain temperature. In the first state they are hard and brittle; in the latter, they are flexible, and are increased in tenacity.

Brass wire appears to undergo some change in its arrangement, by hanging up in a damp room, or in situations where the fumes of acids prevail. It becomes so brittle as not to admit of bending to a right angle. This appears to arise from an increase in its polar form, for heating it red-hot partly restores its malleability.

The fusibility of metals is a very valuable property, since it not only admits of their being cast into almost any form, but the refuse can be made into its original form, which allows of great economy.

Some metals are better fitted for casting than others. It is observed, that all those metals of which we have spoken as being susceptible of the crystalline form, are the best calculated to take fine impressions. At that point in which the metal passes from the liquid to the solid form, a sudden expansion takes place, by which the volume is increased, and, in consequence, presses more strongly against the sides of the mould. This is particularly the case with brass, cast iron, and copper with tin. In forming alloys the most fitted for casting, a simple method offers itself. Let the specific gravity of the solid be as much as possible less than the liquid. In such bodies it will be found that the solid metals will float upon the liquid.

The property which metals possess of reflecting light, is highly important in the arts, sciences, and in common life. The surfaces of many of the metals, when they are smooth and polished, reflect almost all the light which falls upon them. White metals reflect more light than those which are coloured. The hardest metals are best fitted for reflectors, because they assume the finest polish. It has been thought that this property depended upon the density of these substances. This idea, however, seems incorrect, since sodium and potassium, which are less dense than water, appear to possess the power of reflecting light equal to many other metals. It is the great quantity of light which they reflect to which they owe their lustre. The great facility with which metallic bodies conduct heat is of incalculable utility in the arts, and in the economy of human life. The boiling of most fluids would be almost impracticable in any other vessels than those of metal.

This property has been applied to great advantage in the process of drying various articles. Large tubes of metal, being filled with steam, are kept constantly at nearly 212°. The goods to be dried are wrapped round the outside of the tube.

The metal gives its heat with such facility, as to dry the substances upon it in a very little time.

Metals are the best conductors of electricity, and hence are highly useful in electrical science, as well as in preserving the lesser conducting substances from the effects of lightning.

The greater number of the metals are acted upon by the air, especially when aided by heat. Metals were thought by the ancients to be compounds of an earth combined with phlogiston. When these bodies were acted upon by the air, they supposed that the phlogiston was separated, leaving behind a calx, or earth. The ancients did not weigh their products, or else they would have found, that although this imaginary substance phlogiston had escaped, yet the residuum was heavier than the original metal. By the greater accu-

racy of modern experimenters, it has been found that the metal is the simple body, and that, by combining with the oxygen of the atmosphere, the metal is converted into a substance of an earthy appearance, which, in modern chemistry, is called an oxyd of the metal.

The bodies formed by the combination of metals with oxygen, exhibit, as well as the metal, an ample field of utility to man. These bodies, in various forms, are valuable auxiliaries in the healing art. Some of them constitute rich pigments of the utmost importance to the arts. Others are not less valuable to the dyer and the bleacher. Several metallic oxyds are used to great advantage for polishing marble, glass, and metals.

Metals *for Specula*. See Speculum.

Metals, *Colours from*. As metals have a strong texture in their metalline form, so they preserve their natural colours durable, unless corroded or dissolved by particular menstruums, after which their solutions strike particular durable colours, or afford the strongest stains.

Iron dissolved in stale small beer gives the beautiful yellow and different shades of buff colour, used in printing linens and cottons, &c. When sublimed with sal ammoniac it also affords a yellow; and the common iron-moulds made by ink are owing to the iron dissolved in the copperas of which ink is made.

Copper melted with zinc appears of a gold colour; dissolved in aquafortis, it affords a beautiful green; and in any alkali a beautiful blue. And these solutions may be reduced to dry colours by crystallization or evaporation; and the same metal, precipitated out of aquafortis with common salts, gives the turquoise colour to white glass. Tin, a white or colourless metal, affords a light blue colour, when fluxed with antimony and nitre. The same metal is necessary in striking the scarlet dye with aquafortis and cochineal; and its calx, by strong infusion, turns to a glass of an opal colour.

Lead, corroded by the fumes of vinegar, gives the fine white cerus; burnt in a strong naked fire, it becomes the strong red-lead, or minium; and melted into a glass with sand, is of the hyacinth colour. Shaw's Lectures, p. 171.

Silver being dissolved in aquafortis, if chalk be put to the solution, turns of a beautiful purple or amethyst colour; and its own solution, though pale as water, durably stains the nails, skin, or hair, brown or black.

Quicksilver, mixed with brimstone, makes a black mass, and this, by sublimation, affords the beautiful red pigment called cinnabar, or vermilion; and the solution of quicksilver being precipitated with common salt, yields a snow-white powder, which also turns black by being mixed with sulphur.

Gold, dissolved in aqua regia, affords a fine yellow liquor, which stains animal substances beautifully purple; and if the solution be sufficiently weakened with water, and mixed with a solution of tin, a fine red or purple powder may be procured, very useful for staining of glass and pastes to a beautiful red.

It appears, from the experiments of sir Isaac Newton, relating to the changes of colour that take place in pellucid colourless substances, that the less refrangible colours are exhibited by the greater thickness of air, water, and glass; and that as the thickness of those substances is diminished, they reflect the more refrangible colours. Hence he infers, that nothing more is requisite for producing all the colours of natural bodies, than the several sizes and densities of their particles. Accordingly he attributes the colours of permanently coloured bodies to the same cause by which they were produced in colourless substances, *viz.* to the various thicknesses of their component particles. But no experiments were made on permanently coloured bodies, in order to establish the truth of sir Isaac Newton's opinion, till the ingenious Mr. Delaval directed his attention to this subject. From observing the circumstances above recited, and more largely illustrated under the article Colours, it appeared to him, that, if permanently coloured bodies are subject to the same laws as transparent colourless substances are, all such permanently coloured bodies, whenever the size of their particles is diminished, should undergo a change of colour, by ascending from the less refrangible to the more refrangible colours; and that such bodies, when the size of their particles is augmented, should undergo a contrary change, their colour in this case descending from the more refrangible to the less refrangible colours. In order to confirm this conclusion, he made a great variety of experiments with vegetable, animal, and mineral subjects, whereby the size of their particles, upon which their colours depend, might be diminished or increased. The methods which he used, in order to diminish the size of the particles of those bodies which were the subject of inquiry, were by dissolving, attenuating, &c. by means of chemical solvents, heat, putrefaction, dilution, &c. The contrary effects were brought about by such means as are known to condense, incrassate, or unite the particles of bodies into larger masses, as by coagulation, precipitation, evaporation, by diminishing the force of the solvents, &c. The metals afforded him numerous instances in confirmation of the doctrine above explained; for almost every operation, to which they are subject, exhibits a change of colour corresponding to this doctrine. This is particularly the case with regard to the imperfect metals; for every change of their texture is accompanied by a correspondent change of colour. We can only enumerate some of the principal results which Mr. Delaval obtained from a great number of well-conducted experiments. Thus, the green vitriol of iron is changed, in proportion as it is deprived of its solvent part, by exposing it to a strong heat, &c. to yellow, orange, red, and purple; and by a contrary process, *viz.* by a farther attenuation, by means of the phlogisticated lixivium, in the process of Prussian blue, &c. the colour of the iron ascends from green to blue; so that all the primary colours are produced from the same metal, in proportion as its particles are attenuated or incrassated. It appears, likewise, that when iron is divided into very small parts by means of a large quantity of glass, and by a violent heat, its colour is blue; but in proportion as it is less divided, by the mixture of a smaller quantity of glass, or the application of less heat, its colours are green, yellow, and red. From iron dissolved in its several menstrua, colours are produced in proportion as the solvent power of those menstrua is greater or less. Thus, iron dissolved in its strongest acid solvent, the vitriolic acid, gives green; in its weaker acid solvents, the marine and nitrous acids, yellow and orange; and in its weakest acid solvents, the vegetable acids, red. The colours of the calces of iron precipitated from its solution in the vitriolic and nitrous acid, descend from green to yellow, and from yellow to red; whereas the changes of colour arising from the solution of these calces, proceed in a contrary order, and ascend. Mineral substances are also frequently impregnated with iron, and their colours correspond with the state of the iron contained in them.

In the same manner the colours of the solution of mercury in the nitrous acid vary, in proportion as the solvent is extricated from it, from yellow to orange, and then to red. Thus also, those substances which have the greatest affinity with the acid of the corrosive sublimate produced

by the ſolution of mercury in the marine acid, diſengage from its ſolution a red precipitate; and thoſe, whoſe affinity with it is leſs, produce a yellow one. But theſe colours are liable to ſome variation, according to the greater or leſs quantity of acid in the ſolution. Mercury diſſolved in the vitriolic and in the vegetable acids, exhibits, in proportion as its ſolvent is taken from it, the ſame colours which, under ſimilar circumſtances, are afforded by that metal diſſolved in the other acids. All theſe mercurial preparations become red, when they are deprived of the principal part of their menſtruum; and mercury calcined by heat, without the addition of any acid, acquires the ſame colour. Its colour, however, is ſubject to variation, from the action of its ſolvents; and thus the phoſphoric acid changes the red to yellow and white. The ſame law obtains in the changes of colour to which the mineral mangaueſe is ſubject; for Mr. Delaval found, that by means of the different degrees of power in the ſeveral ſolvents, theſe colours were produced in their regular priſmatic order, *viz.* yellow, green, blue, purple, and red. The various phenomena of the ſympathetic ink of M. Hellot conform to the ſame law, and are urged by Mr. Delaval as arguments to eſtabliſh it. Heat and cold, he obſerves, are not neceſſary agents in the production or ſuppreſſion of the colour. But it appears, that the alterations are effected by the moiſture of the air, attracted by the ſaline matter when cold, and expelled from it when heated. When this ink is expoſed to a moderate heat, in a white China cup, and when the greater part of the water is evaporated, the ſaline matter becomes green. This colour ariſes from a ſuperfluous quantity of the marine acid, which ſoon flies off, and leaves the remaining part blue, ſlightly inclining to green. It alſo forms a hard dry maſs, which, in a few minutes after its removal from the fire, grows moiſt, and aſſumes a light red colour. Theſe alterations may be often renewed, by alternately heating and cooling the coloured matter; which does not again become green, after the ſuperfluous marine acid is once evaporated. But a drop of ſpirit of ſalt, added to the red or blue maſs, immediately renders it green. When preparations of cobalt are acted upon merely by heat, the order of the changes of colour effected in them, is ſuch as, in other inſtances, conſtantly ariſes from that means of attenuation. Thus, when the yellow ſolution of this mineral, in the marine acid, is heated, it aſſumes a green colour, paſſing from a leſs to a more refrangible colour. When this ſolution is cooled, the yellow is reſtored.

Mr. Delaval obſerves, that as the inflammable matter, in the entire metals, acts ſtrongly on the rays of light, it is neceſſary to calcine or to divide them into extremely minute particles, in order to examine ſeparately the action of the calx, or fixed matter, on the rays of light. In order, therefore, to examine all the metals in the like circumſtances, by reducing them into the ſmalleſt particles, and depriving them of their phlogiſton as much as poſſible, he expoſed each of them, united with a proper quantity of the pureſt glaſs, without any additional ingredient, to the greateſt degree of fire which they are capable of bearing, without having all colour whatever deſtroyed. In this ſtate it appears, from a variety of experiments and facts, that they actually do, without any exception, exhibit colour in the order of their denſities as follow: gold, red; lead, orange; ſilver, yellow; copper, green; and iron, blue. He has alſo ſhewn that the other preparations of the metals, *viz.* their ſolutions, precipitates, cryſtals, &c. do for the moſt part exhibit the ſame colour, in the order of their denſities, though not ſo invariably as their glaſſes; ſome ſmall variation of colour happening in the more imperfect metals, probably from a change of denſity in their different preparations. Thus, gold acquires a red colour, by a minute diviſion of its particles, without any addition. In the proceſs of calcining lead in the furnace, the firſt of the primary colours which it acquires is yellow; the calx paſſing from that colour through orange into red. This variety of colours proceeds from the imperfection of the metal; which, probably, during its calcination (as our author ſuppoſed), receives a ſmall portion of phlogiſton, as well as air; for the effect of ſuch an union muſt probably be a change of colour from orange to red: as ſir Iſaac Newton has ſhewn, that bodies reflect more ſtrongly in proportion as they poſſeſs more phlogiſton; and that the leſs refrangible colours require a greater power to reflect them. The preparations of ſilver are yellow; the two moſt imperfect metals, copper and iron, being very eaſily acted upon by almoſt all menſtrua, the colours of their ſolutions, &c. *viz.* green and blue, are apt to change into each other's order; the copper in ſome ſolvents becoming blue, and the iron green, and in other ſolvents *vice verſâ*; which probably depends on the increaſe or diminution of their denſities. The preparations, &c. of mercury have been already examined. The ſpecific gravity of platina being nearly equal to that of gold, it is found, agreeably to the Newtonian doctrine, confirmed by Mr. Delaval, that the precipitates and cryſtals obtained from ſolutions of this metal are red; and that a ſolution of it in aqua regia to perfect ſaturation is of a dark red, though, when diluted, yellow. Delaval's Experimental Inquiry into the Cauſe of the Changes of Colours in opaque and coloured Bodies, &c. 1777, paſſim. Phil. Tranſ. vol. lv. art. 3, p. 10, &c.

Mill

MILL, in propriety, denotes a machine for grinding corn, &c. but, in a more general signification, is applied to all machines whose action depends on a circular motion.

Of these there are several kinds, according to the various methods of applying the moving power; as water-mills, wind-mills, mills worked by horses, &c.

Few people are ignorant, that corn is ground by two mill-stones, placed one above the other, without touching.

The lower mill-stone is immoveable, but the upper one turns upon a spindle. The opposite surfaces of the two stones, which act to grind the corn, are not plane or flat; but the upper one is hollow, and the under one swells up; each of them being of a conic figure, whose axis indeed is very short, in proportion to the diameter of its base; for the upper one being six feet in diameter, is hollowed but about one inch at its centre; and the lower one rises but about three-fourths of an inch. These two mill-stones come nearer and nearer towards their circumference, whereby the corn that falls from the hopper has room to insinuate between them as far as two-thirds of the radius, which is the place where it begins to be ground, and where it makes the greatest resistance that it is capable of; the space between the two stones being in that place about but two-thirds or three-fourths of the thickness of a grain of corn. But as the millers have the liberty of raising or sinking the upper stone a little, they can proportion its distance from the lower one, according as they would have the flour finer or coarser.

In order to cut and grind the corn, both the upper and under mill-stones have channels or furrows cut in them, proceeding obliquely from the centre towards the circumference. And these furrows are each cut perpendicularly on one side, and obliquely on the other, into the stone; which gives each furrow a sharp edge, and in the two stones, they come, as it were, against one another, like the edges of a pair of scissars; and so cut the corn to make it grind the easier, when it falls upon the places between the furrows. These are cut the same way in both stones when they lie upon their backs, which makes them run cross-ways to each other, when the upper stone is inverted by turning its furrowed surface towards that of the lower. For if the furrows of both stones lay the same way, a great deal of the corn would be drove onward in the lower furrows, and so come out from between the stones without ever being cut. When the furrows become blunt and shallow by wearing, the running stone must be taken up, and both stones new drest with a chissel and hammer. But, by this repeated operation, their thicknesses, and consequently their weight, diminish; and it is observed, that when they come to have but three-quarters, or half of the thickness which they had when new, they produce but three-quarters or half the flour which they yielded at the beginning.

The circular motion of the upper mill-stone brings the corn out of the hopper by jerks, and causes it to recede from the centre towards the circumference, where, being quite reduced to flour, it is thrown out of the mill, by the centrifugal force of the stone, through a hole provided on purpose.

The diameter of common mill-stones, according to Dr. Desaguliers, is from five to seven feet, and their thickness, twelve, fifteen, or eighteen inches: they last thirty-five or forty years, and when they have been long used, so that their thickness is considerably diminished, they are cut anew, to give their surface a contrary figure to what they had before: so that the upper mill-stone is made the lower.

In water-mills, the momentum of the water is the moving power, and the attrition of the two stones in grinding is the force to be overcome. Of these there are two kinds, *viz.* those where the force of the water is applied above the wheel, and those where it is applied below the wheel; the former being called over-shot, and the latter under-shot mills: and to these we may add a breast-mill, where the water strikes against the middle of the wheel.

In a common breast-mill, where the fall of water may be about ten feet, A A, (*Plate* XXIII. *Mechanics, fig.* 1.) is the great wheel, which is generally about seventeen or eighteen feet diameter, from *a* the outermost edge of any float board, to *b*, that of its opposite float. To this wheel the water is conveyed through a channel, and falling upon the wheel, turns it round. On the axis B B, of this wheel, and within the mill-house, is a wheel D, about eight or nine feet diameter, having sixty-one cogs, which turn a trundle E, containing ten upright staves or rounds; and when this is the number of cogs and rounds, the trundle will make $6\frac{1}{10}$ revolutions for one revolution of the wheel. The reason of adding an odd cog, called the hunting cog, to the wheel, is this; that, as every cog comes to the trundle, it may take the next staff or round behind the one which it took in the former revolution, and thus it will wear all the parts of the cogs and rounds which work upon one another equally, and to equal distances from one another in a little time; and make a true uniform motion throughout the whole work. The trundle is fixed upon an iron axis called the spindle, the lower end of which turns in a brass foot, fixed at F, in the horizontal beam S T, called the bridge-tree; and the upper part of the spindle turns in a wooden bush fixed into the lower mill-stone, which lies upon beams in the floor Y Y. The top part of the spindle above the bush is square, and goes into a square hole in a strong iron cross, *a b c d*, (*fig.* 2.) called the rynd; under which, and close to the bush, is a round piece of thick leather upon the spindle, which it turns round at the same time as it does the rynd. The rynd is let into grooves in the under surface of the running mill-stone G, (*fig.* 1.) and so turns it round in the same time that the trundle E is turned round by the cog-wheel D. This mill-stone has a large hole quite through its middle, called the eye of the stone, through which the middle part of the rynd and upper end of the spindle may be seen; whilst the four ends of the rynd lie hid below the stone in their grooves.

The end T of the bridge-tree T S (which supports the upper mill-stone G upon the spindle) is fixed into a hole in the wall; and the end S is let into a beam Q R called the brayer, whose end R remains fixed in a mortise: and its other end Q hangs by a strong iron rod P, which goes through the floor Y Y, and has a screw-nut on its top at O; by the turning of which nut, the end Q of the brayer is raised or depressed at pleasure; and, consequently, the bridge-tree T S and upper mill-stone. By this means the upper mill-stone may be set as close to the under one, or raised as high from it, as the miller pleases. The nearer the mill-stones are to one another, the finer they grind the corn; and the more remote from one another, the coarser.

The upper mill-stone G is inclosed in a round box H, which does not touch it any where; and is about an inch distant from its edge all around. On the top of this box stands a frame for holding the hopper *k k*, to which is hung the shoe I, by two lines fastened to the hind-part of it, fixed upon hooks in the hopper, and by one end of the

crook-ftring K faftened to the fore-part of it at i; the other end being twifted round the pin L. As the pin is turned one way, the ftring draws up the fhoe clofer to the hopper, and fo leffens the aperture between them; and as the pin is turned the other way, it lets down the fhoe, and enlarges the aperture.

If the fhoe be drawn up quite to the hopper, no corn can fall from the hopper into the mill; if it be let a little down, fome will fall: and the quantity will be more or lefs, according as the fhoe is more or lefs let down. For the hopper is open at bottom, and there is a hole in the bottom of the fhoe, not directly under the bottom of the hopper, but forwarder towards the end i, over the middle of the eye of the mill-ftone.

There is a fquare hole in the top of the fpindle, in which is put the feeder e (*fig.* 2.); this feeder (as the fpindle turns round) jogs the fhoe three times in each revolution, and fo caufes the corn to run conftantly down from the hopper, through the fhoe, into the eye of the mill-ftone, where it falls upon the top of the rynd, and is, by the motion of the rynd and the leather under it, thrown below the upper ftone, and ground between it and the lower one. The violent motion of the ftone creates a centrifugal force in the corn going round with it, by which means it gets farther and farther from the centre, as in a fpiral, in every revolution, until it be thrown quite out; and, being then ground, it falls through a fpout M, called the mill-eye, into the trough N. When the mill is fed too faft, the corn bears up the ftone, and is ground too coarfe; and befides, it clogs the mill fo as to make it go too flow. When the mill is too flowly fed, it goes too faft, and the ftones, by their attrition, are apt to ftrike fire againft one another. Both which inconveniencies are avoided by turning the pin L backwards or forwards, which draws up or lets down the fhoe; and fo regulates the feeding as the miller fees convenient.

Sometimes, where there is a fufficient quantity of water, the cog-wheel in *fig.* 1. turns a large trundle, on whofe axis is fixed a horizontal wheel, with cogs all around its edge, turning two trundles at the fame time; whofe axis or fpindles turn two mill-ftones. When there is not work for them both, either may be made to lie quiet, by taking out one of the ftaves of its trundle, and turning the vacant place towards the horizontal cog-wheel. And there may be a wheel fixed on the upper end of the great upright axle of this wheel for turning a couple of boulting-mills; and other work for drawing up the facks, fanning and cleaning the corn, fharpening of tools, &c. As the water acts upon an over-fhot mill both by impulfe and weight, fo does it likewife upon a breaft-mill, or that where the water comes upon the breaft or middle part of the wheel: and here, though the weight of the water is not fo great as in the over-fhot mill, being contained in the buckets of the lower quarter only; yet the impulfe of the water is much greater, the height of the water being increafed nearly the femi-diameter of the great wheel, all other things being equal. If the height of the water remain the fame, the aperture of the penftock muft be enlarged to nearly twice the area, that the force may be the fame; fo that to produce the fame effect, twice as much water is neceffary for the breaft-mill as for an over-fhot one, every thing elfe being the fame.

Mr. Fergufon obferves, that where there is but a fmall quantity of water, and a fall great enough for the wheel to lie under it; the bucket or over-fhot wheel is always ufed. But where there is a large body of water, with a little fall, the breaft or float-board wheel muft take place. As to the under-fhot mill, it is evident there can be only the impulfe from the water; and therefore, the height of the water remaining the fame, there muft be a larger aperture of the penftock for the difcharge of a greater quantity of water in the fame time, in order to produce the fame effect as the over-fhot or breaft-mill; whence a greater expence of water will be made here than in any other mill, and can only be fupplied for a conftancy by a river; and where this can be had, the under-fhot is the eafieft, cheapeft, and moft fimple ftructure, of which a mill is capable. Dr. Defaguliers, having had occafion to examine many under-fhot and over-fhot mills, generally found that a well made over-fhot mill ground as much corn, in the fame time as an under-fhot mill with ten times lefs water; fuppofing the fall of water at the over-fhot to be twenty feet, and at the under-fhot to be about fix or feven feet: and he generally obferved, that the wheel of the over-fhot mill was of fifteen or fixteen feet diameter, with a head of water of four or five feet, to drive the water into the buckets with fome momentum.

Mr. Fergufon has given the following directions how to conftruct water-mills, fo as to be in the greateft degree of perfection; and alfo a table calculated from his rules, for the fake of thofe mill-wrights who either cannot calculate, or do not like to take the trouble.

When the float-boards of the water-wheel move with a third part of the velocity of the water that acts upon them, the water has the greateft power to turn the mill: and when the mill-ftone makes about fixty revolutions in a minute, it is found to do its work the beft. For, when it makes but about forty or fifty, it grinds too flowly, and when it makes more than feventy, it heats the meal too much, and cuts the bran fo fmall, that a great part thereof mixes with the meal, and cannot be feparated from it by fifting or boulting. Confequently, the utmoft perfection of mill-work lies in making the train fo, as that the mill-ftone fhall make about fixty turns in a minute when the water-wheel moves with a third part of the velocity of the water. To have it fo, obferve the following rules:

1. Meafure the perpendicular height of the fall of water, in feet, above the middle of the aperture, where it is let out to act by impulfe againft the float-boards on the loweft fide of the under-fhot wheel.

2. Multiply this conftant number 64.2882, by the height of the fall in feet, and extract the fquare root of the product, which fhall be the velocity of the water at the bottom of the fall; or the number of feet the water moves *per* fecond.

3. Divide the velocity of the water by 3; and the quotient fhall be the velocity of the floats of the wheel in feet *per* fecond.

4. Divide the circumference of the wheel, in feet, by the velocity of its floats; and the quotient fhall be the number of feconds in one turn or revolution of the great water-wheel on whofe axis the cog-wheel that turns the trundle is fixed.

5. Divide 60 by the number of feconds in a turn of the water-wheel or cog-wheel; and the quotient fhall be the number of turns of either of thefe wheels in a minute.

6. By this number of turns divide 60 (the number of turns the mill-ftone ought to have in a minute) and the quotient fhall be the number of turns the mill-ftone ought to have for one turn of the water or cog-wheel. Then,

7. As the required number of turns of the mill-ftone in a minute is to the number of turns of the cog-wheel in a minute, fo muft the number of cogs in the wheel be to the number of ftaves in the trundle on the axis of the mill-ftone, in the neareft whole number that can be found. By thefe rules the following table is calculated; in which the diameter of the water-wheel is fuppofed to be 18 feet, (and confe-

quently its circumference $56\frac{4}{7}$ feet,) and the diameter of the mill-ftone to be five feet.

of the water in feet *per*	Velocity of the		ired number of for each turn of the	Cogs.	Stav.	ber of s o: the mill-ftone for the wl hy e.cogs and fta	of turns of the mill-ft by thefe cogs and ftaves.
8.02	2.67	2.63	21.20	127	6	21.17	59.91
11.40	3.72	4.00	15.00	105		15.00	60.00
13.89	4.63	4.91	12.22	98		12.25	60.14
16.04	5.35	5.67	10.58	95		10.56	59.87
17.93	5.98	6.34	9.46	85		9.44	59.84
19.64	6.55	6.94	8.64	78		8.66	60.10
21.21	7.07	7.50	8.00	72		8.00	60.00
22.68	7.56	8.02	7.48	67		7.44	59.67
24.05	8.02	8.51	7.05	70	10	7.00	59.57
25.35	8.45	8.97	6.69	67	10	6.70	60.09
26.59	8.86	9.40	6.38	64	10	6.40	60.16
27.77	9.26	9.82	6.11	61	10	6.10	59.90
28 91	9.64	10.22	5.87	59	10	5.90	60.18
30.00	10.00	10.60	5.66	56	10	5.60	59.36
31.05	10.35	10.99	5.46	55	10	5.40	60.48
32.07	10.69	11.34	5.29	53	10	5.30	60.10
33.06	11.02	11.70	5.13	51	10	5.10	59.67
34.02	11.34	12.02	4.90	50	10	5.00	60.10
34.95	11.65	12.37	4.85	49	10	4.80	60.61
35.86	11.92	12.68	4.73	47	10	4.70	59.59

Example.—Suppofe an under-fhot mill is to be built where the perpendicular height of the fall of water is nine feet: it is required to find how many cogs muft be in the wheel, and how many ftaves in the trundle, to make the mill-ftone go about 60 times round in a minute, while the water-wheel-floats move with a third part of the velocity with which the water fpouts againft them from the aperture at the bottom of the fall.

Find 9 (the height of the fall) in the firft column of the table; then againft that number, in the fixth column, is 70, for the number of cogs in the wheel, and 10 for the number of ftaves in the trundle: and by thefe numbers, we find in the eighth column that the mill-ftone will make $59\frac{57}{100}$ turns in a minute, which is within half a turn of 60, and near enough for the purpofe; as it is not abfolutely requifite that there fhould be juft 60 without any fraction: and throughout the whole table the number of turns is not quite one more or lefs than 60.

The diameter of the wheel being eighteen feet, and the fall of water nine feet, the fecond column fhews the velocity of the water at the bottom of the fall, to be $24\frac{5}{100}$ feet *per* fecond; the third column the velocity of the float-boards of the wheel to be $8\frac{2}{100}$ feet *per* fecond; the fourth column fhews that the wheel will make $8\frac{51}{100}$ turns in a minute; and the fixth column fhews that for the mill-ftone to make exactly 60 turns in a minute, it ought to make $7\frac{5}{100}$ (or feven turns and five hundred parts of a turn) for one turn of the wheel.

Dr. Barker has invented a water-mill, that has neither wheel nor trundle: this is reprefented in *fig.* 3, in which A is a pipe or channel that brings water to the upright tube B. The water runs down the tube, and thence into the horizontal trunk C, and runs out through holes at *d* and *e* near the ends of the trunk on the contrary fides thereof.

The upright fpindle D is fixed in the bottom of the trunk, and fcrewed to it below by the nut *g*; and is fixed into the trunk by two crofs-bars at *f*: fo that if the tube B and trunk C be turned round, the fpindle D will be turned alfo.

The top of the fpindle goes fquare into the rynd of the upper mill-ftone H, as in common mills; and as the trunk, tube, and fpindle turn round, the mill-ftone is turned round thereby. The lower, or quiefcent mill-ftone, is reprefented by I; and K is the floor on which it refts, and wherein is the hole L for letting the meal run through, and fall down into a trough which may be about M. The hoop or cafe that goes round the mill-ftone refts on the floor K, and fupports the hopper, in the common way. The lower end of the fpindle turns in a hole in the bridge-tree G F, which fupports the mill-ftone, tube, fpindle, and trunk. This tree is moveable on a pin at *h*, and its other end is fupported by an iron rod N fixed into it, the top of the rod going through the fixed bracket O, and having a fcrew-nut *o* upon it, above the bracket. By turning this nut forward or backward, the mill-ftone is raifed or lowered at pleafure.

Whilft the tube B is kept full of water from the pipe A, and the water continues to run out from the ends of the trunk; the upper mill-ftone H, together with the trunk, tube, and fpindle, turns round. But if the holes in the trunk were ftopt, no motion would enfue; even though the tube and trunk were full of water. For,

If there were no hole in the trunk, the preffure of the water would be equal againft all parts of its fides within. But, when the water has free egrefs through the holes, its preffure there is entirely removed; and the preffure againft the parts of the fides which are oppofite to the holes, turns the machine. See Defaguliers's Exp. Phil. vol. ii. p. 417, &c. p. 431, &c. p. 459, &c. Fergufon's Mechanics, p. 45, &c. 4to. ed. and Supp. p. 10. See alfo on this fubject, an elaborate paper of Mr. Smeaton, containing an account of a number of experiments, in order to eftimate the natural powers of water and wind to turn mills, in the Phil. Tranf. vol. li. art. 18 p. 100, &c.

The defcription of a mill, which we have given above in the words of the late ingenious Mr. Fergufon, is very correct. The improvements of late years, which have been made in mills for grinding corn, relate to the manner of their conftruction, and the proportions of the wheel-work, for giving motion to the mill-ftones, by which the grinding is performed in the manner defcribed. The late Mr. John Smeaton, F.R.S., was celebrated for his accuracy and judgment in the proportions of his mills, particularly thofe turned by water. We fhall, under the article WATER-*Wheels*, give fome account of his principles; and under this head we fhall defcribe a fteam flour-mill, which was erected from his defigns, at the victualling houfe for the navy at Deptford, in 1781. This was before the fteam-engine of Mr. Watt was brought to the perfection it has fince attained; and as the old atmofpheric engine was thought to be unfit for producing a rotatory motion, Mr. Smeaton erected a common fteam-engine to pump up water for the fupply of a large overfhot water-wheel, which actuated the mill. *Fig.* 1. of *Plate* XXXIV. *Mechanics*, reprefents the whole mill, by a longitudinal fection of the houfe; and *fig.* 2,

another section, taken perpendicular to the former. The mill is double, that is, the water-wheel, A A, is situated between two buildings, only one of which is represented in *fig.* 2; and the wall, B B, of the other is one side of a house, containing exactly the same machinery as that which is delineated. Over the water-wheel two large cisterns, or troughs, C, D, are placed, communicating with each other by a large iron pipe E, *fig.* 1; and one of these troughs, C, has a pipe or trough, leading water into it, from the pump of the steam-engine supplying the water for the mill: in the other trough, D, is a shuttle *a*, which being raised up, permits the water to issue from a hole in the end of the trough, and fly forwards horizontally through a proper shute, or pentrough, into the buckets of the wheel A. The form of these buckets is shewn by *fig.* 1, a portion of the wheel being represented in section for that purpose. The buckets, which are thus filled at the top of the wheel, descend by their weight, turning the wheel round, till they come to the lowest part of the wheel; and here, by the buckets becoming inverted, the water is discharged from them, and they go up empty to the top of the wheel, where they are filled again from the trough. In this manner, one side of the wheel being always loaded by the buckets full of water, and the other side being empty, it has a constant tendency to turn round. The axis of the wheel has a large spur-wheel, E, fixed upon its extreme end, which being furnished with a double row of cogs, as shewn in *fig.* 2, communicates motion to the lanterns or trundles, F, G, one above, and the other below it: the latter, G, is fixed upon the end of an horizontal shaft H H, extending beneath the mill-stones, situated at I I and L: it actuates the upper stone of each pair, by means of crown or face-wheels K, which turn the pinions fixed at the lower ends of the respective spindle *d d*. The upper trundle, F, is fixed upon a shaft, which carries two face-wheels, *e*, *f*: the teeth of these wheels are opposite to each other, and either of them can be made to work a pinion, *g*, *fig.* 1, fixed upon the end of an axis *h*, which at the other end has a cog-wheel turning a pinion at *k*, on the end of the spindle of a machine, M, for dressing flour. This machine consists of a hollow cylinder or frame, covered with wire-cloth of different degrees of fineness; the finest being at the end A, which is the most elevated, for the axis of the cylinder is inclined in the direction of the dotted line: every one of the lengths, as it goes towards the other end, is covered with a coarser kind of wire-cloth, for sifting the flour. Within this cylinder, which is stationary, a reel is situated; its axis being exactly in the centre of the cylinder, and turned round by the pinion *k*: the rails of this reel are provided with hair brushes, which, as they revolve, brush against the interior wire surface of the cylinder. The machine is provided with a shoe or jigger, very similar to that of the mill-stones, to bring down the flour or meal through a trough, from the floor above, where it is kept after being ground: the meal, being by this means gradually fed into the cylinder, is, by the motion of the brushes on the reel, sifted or rubbed through the wire: the finest of the flour will of course go through at the upper end, but no other kind; the second through the next division, and so on till the bran falls out at the end of the cylinder, being too coarse to go through any of the wires. The cylinder is enclosed in a tight and close box M, to prevent waste by the flour flying about; and the box has partitions, which divide it into as many lengths as the cylinder has different kinds of wire. Thus each division of the box receives a different quality of flour; and spouts being fixed, which go down into the floor beneath, sacks can be filled at them without waste or inconvenience.

The pinion *g*, for turning the dressing machine, can be made to turn either way about, by engaging it with the teeth of either of the cog-wheels *e*, *f*, which acting on the opposite sides of the pinion *g*, give the means of turning it in either direction at pleasure. The pinion is of such a diameter, that it cannot be engaged with both wheels at once; and the upright lever *r*, which supports the pivot of its axis *h*, can be thrown to either side, as is shewn in *fig.* 2: for its lower end moves on a centre at the floor, and at top it is guided by a groove in a piece of wood, fixed to the ceiling, and can be fastened at either side by a pin, so as to throw the pinion in gear with either *e* or *f*. The object of this contrivance is, that when the machine, M, has for a long time been running in one direction, and its brushes become worse, or bent on one side, its motion may be reversed, to give them an equal wear on the opposite side. The wheel, *e*, has another fixed to it at the back (see *fig.* 2.), which actuates a cog-wheel N, upon the end of a roller R, having a rope wound round it, for drawing up sacks of corn or flour from one floor of the mill to another. This rope passes upwards from the roller to the roof of the building, where it passes over a pulley, and thence descends through square holes in the several floors to the ground. These holes are covered by double doors, opening upwards, so that a sack, being drawn up, opens the door, which falls down as soon as it has passed. The wheel, N, of the sack-roller can be disengaged at pleasure from the cog-wheel, *e*, which turns it; and then the rope can be unwound and run down again, to fetch up another sack. This disengagement of the wheel is effected by the same means as described of the upright lever *r*; and a line being conducted from the top of the lever, over proper pullies, into various parts of the mill, the miller can, by pulling this line, disengage the roller at pleasure, to draw up or let down a sack. A pinion and shaft, similar to *g* and *h*, *fig.* 1, may be placed on the opposite side of the wheels, *e* and *f*, to work another dressing machine at the opposite side of the mill, or what is called a bolting machine. This is rather of a different construction, being the original flour-dressing machine: it consists of a reel like the former, but without any brushes; and upon this, instead of a wire-cylinder, a cloth like a sack, cut open at the bottom, is fastened, and revolves with it; the flour, being introduced by a feeding-shoe into this, is sifted round in the revolving cloth, and the fine flour passes through. To prevent the flour accumulating at any one side of the cloth into a bag, and swinging round with it, without sifting, four rails are fixed in the machine, parallel to the axis; and if the cloth swings out by the weight of the flour within it, the cloth strikes against these rails, and the flour is thus shaken through it into the chest or case of the machine.

The lower figures of the plate contain the developement of the parts of the mill, tending to explain their construction. *Figs.* 3, 4, and 5, shew the cast-iron axis for the water-wheel; N is the cylindric shaft, and *b*, *b*, its two necks, which lay on bearings in the wall of the mill, and bear the weight: beyond these necks the axis has a square box, O O, at each end, for framing the great cog-wheels upon. The manner of attaching the arms of the great water-wheel to the shaft is this: two circular plates or flaunches, P, P, *fig.* 3, are cast upon the axis; and against each of these 12 arms, Q, Q, are bolted: they are placed against the flaunch, tending to the centre, and the spaces between them are filled up by wooden pieces, as shewn by *r*, *r*, *r*, *fig.* 4: two iron rings, R and S, are placed over the arms, and a bolt put through each arm, to attach it to the flaunch, and to the axis; the wooden pieces, *r*, *r*, are kept in their places by a wedge driven through each, within the great hoop R, and by means of these wedges the pieces, *r*, *r*, can

at any time be drawn up towards the centre, to hold all the arms fast in their places.

This method of framing water-wheels was used with great success by Mr. Smeaton in many instances, and was found to answer the purpose extremely well, being a great improvement upon the old method of mortising the arms into a wooden shaft.

Figs. 6, 7, and 8, shew one of the spindles for the millstones H and L, *fig.* 2: it is a straight iron axis, *d*, formed to a pivot, *s*, at the lower end, which rests and turns in a piece of brass: near the upper end of the spindle another neck or pivot, *t*, is formed, and runs in a collar, in the centre of the nether or lower mill-stone, whilst the upper one is hung upon the arms of an iron cross T: see also *fig.* 7, fitted with a square upon the top of the spindle. On the lower part of the spindle the pinion Z, which gives it motion, is fixed: it has a square hole through it, fitting on the square spindle, and iron crosses are fixed both at top and bottom of the block of wood forming the body of the pinion: in this iron are two screws (see *fig.* 8.), which, being screwed fast, fix the pinion firmly to the spindle, its weight being supported by a wedge, *v*, put through a hole in it; but when this wedge is withdrawn, and the screws slackened, the pinion falls down so low upon the spindle, that its teeth are clear of the teeth of the cog-wheels *k*, *fig.* 2, and in this state the spindle and mill-stone upon it will stand still, though the mill is going. The spindle foot, *s*, rests in a brass socket, fixed in a lever *w*, *figs.* 1 and 2, called the bridge-tree: its fulcrum is in the solid wall, W, *fig.* 1, at one end, and the other rests on the middle of a second lever X, perpendicular to the former, called the brayer, one end of which has a fulcrum in the framing, *fig.* 2, and the other is supported by a screw, which the miller turns round, to elevate or depress the upper stone, and adjust the distance between them at pleasure, according as he wishes to grind finer or coarser flour. The upper part of the mill before us is used as a store-house for corn, which is drawn up in sacks by the tackle into the roof, and there emptied into binns, or different compartments, of the upper floor: from these it is let down to the mill-stones, and ground into meal. The spouts from the stones lead the meal into sacks, which, when full, are drawn up to the top of the house again, and emptied out into a flour binn, situated over the dressing machine M, which separates it into various qualities for use.

The mills which grind for the London market use three dressing machines: the finest flour is that which has been passed through a wire-cloth of 64 *per* inch, when the meal is dressed the first time; the other part of the cylinder is coarse wire, which suffers a coarse meal, called middlings, to pass through it; but the bran and coarse pollard fall out at the end of the cylinder. The middlings are ground over again in a pair of mill-stones, which are rather dull, and become unfit for grinding corn, without dressing them again: then, after this second grinding, the meal is dressed in the cloth machine, called the bolting cloth, which takes out the second flour, and the pollard comes out at the end of the cloth: the bran and the pollard together are now put into the clearing-off machine, which is a coarse wire-cylinder of the kind we have described, and by it is separated into hog pollard, which is the finest sort; 2d, horse pollard; and, 3d, bran. A pair of mill-stones will grind five bushels of wheat *per* hour, when in good condition; but require to be taken up and dressed once a week, if used constantly. This dressing is done by picking the surface of the stone over with the mill-pick, to cut the grooves and furrows sharp, that they may grind and cut the corn between them.

Persons riotously assembling and destroying, or maliciously burning, any wind-saw mill, wind-mill, or water-mill, &c. shall be guilty of felony, without benefit of clergy, by 9 Geo. III. c. 29. Prosecution to be commenced within eighteen months after the offence committed. By 41 Geo. III. c. 24. the damages occasioned by demolishing any such mill by persons riotously assembled, may be sued for and recovered in the manner provided for by 1 Geo. stat. 2. c. 5. respecting the demolishing of churches and other buildings. (See Riot.) By 43 Geo. III. c. 58. any person who shall maliciously set fire to any mill in the possession of any other person, or of any body corporate, shall be guilty of felony, without benefit of clergy.

Water-mills have long been great nuisances to agriculture, by preventing the use of the streams on which they stand, in many cases, in irrigating and flooding the adjoining lands, by which much improvement is kept back, that would otherwise take place. They are also injurious by obstructing and damming up the water in numerous instances, so as to render it stagnant on the ground above. Wind and steam may, however, be applied as the moving powers of mills without producing any such effects, and are, of course, the most proper powers to be employed.

The ancient feudal custom of obliging tenants to grind at the lord's mills, is now almost wholly done away. Draining or lifting-mills are often extremely useful in discharging water from low flat lands in many situations. The moving power in these is commonly wind. See Mill, in *Mechanics*.

By an ancient ordinance the toll for grinding shall be taken either to the 20th or 24th corn; and yet, in some places, millers claim and take the 16th part: but Mr. Dalton says, that the miller should take but one quart for grinding one bushel of hard corn, and if he carry back the grist to the owner he may take two quarts of such corn, *i. e.* wheat rye, and meslin, (wheat and rye mixed.) For malt he shall take half as much as for hard corn. By Holt ch. just. the toll of a mill must be regulated by custom, and if the miller take more than the custom warrants, it is extortion: but if it be a new mill, the miller is not restrained to any certain toll. (1 L. Raym. 149.) In some places the tenants are bound to have their corn ground at the lord's mill. When a miller, upon information given on oath to any magistrate, is suspected of adulterating meal or flour, the house, mill, &c. of such miller may be entered under the authority of a warrant of a magistrate, at all seasonable times of the day, to search for discovery, and if such adulterated meal or flour be found, it may be seized by the officer executing the warrant, seized by the magistrate to whom it is carried, and disposed of at his discretion. (31 Geo. III. c. 29.) A miller who hath corn given him to grind, and who charges for that which is bad, is indictable; and he may be guilty of felony by taking away any part with an intent to steal it. (Hawk. c. 33.) Millers are not to be common buyers of any corn, with a view to sell the same again, either in corn or meal. (Dalt. c. 122.) By 36 Geo. III. c. 85, every miller shall keep balances and weights according to the standard of the exchequer, which may be examined by a person appointed for this purpose by 35 Geo. III. c. 102; and in default thereof the miller shall forfeit not exceeding 20*s*. &c. &c. Millers may be required to weigh corn, and, on refusal, shall forfeit not exceeding 40*s*. Millers are to deliver the whole produce of corn when ground, if required, allowing for waste in grinding and dressing, and for toll when taken; and if such

corn ſhall weigh leſs than the full weight, ſuch miller ſhall, for every buſhel of corn deficient in weight, forfeit not exceeding 1*s.* and alſo treble the value of ſuch deficiency. When toll is taken, it ſhall be deducted before the corn ſhall be put into the mill. No miller ſhall demand corn for toll, but in lieu thereof ſhall be entitled to payment in money, under penalty of forfeiting not exceeding 5*l.*: excepting when perſons ſhall not have money to pay for grinding, and alſo, that this ſhall not extend to mills called "Soke-mills," or ſuch ancient mills as are eſtabliſhed by cuſtom and the law of the land, which mills ſhall continue to take toll as they have been accuſtomed to do. Every miller is required to put up in his mill a table of the prices in money, or of the amount of toll or multure, on pain of forfeiting 20*s.* for every ſuch offence.

Mills, *Wind*, are, with reſpect to their working parts, little different from thoſe of water-mills; but they are turned by the force of wind gathered in their ſails.

Of theſe, ſome are called *vertical*, others *horizontal*, according to the poſition of the ſails; or, rather, according to the direction of their motion, with regard to the horizon.

For the beſt form of horizontal ſails, and alſo for determining the poſition of the axis of wind-mills, ſee Wind-*mill* and Mechanics.

Mills, *Portative* or *Hand*, are thoſe kept in motion by the hand; or elſe whoſe mill-ſtones are turned, or piſtons driven by the force of horſes or other beaſts. Thus, if the cog-wheel D, (*Plate* XXXIII. *Mechanics*, *fig.* 1.) be made about eighteen inches diameter, with thirty cogs, the trundle as ſmall in proportion, with ten ſtaves, and the mill-ſtones be each about two feet in diameter, and the whole work be put into a ſtrong frame of wood, as repreſented in the figure, the engine will be a hand-mill for grinding corn or malt in rivate families. And then it may be turned by a winch nſtead of the wheel A A; the mill-ſtone making three revolutions for every one of the winch. If a heavy fly be put upon the axle B, near the winch, it will aſſiſt greatly in regulating the motion.

If the cog-wheel that turns the trundle or trundles of a mill be placed horizontally, horizontal levers may be fixed into its vertical axis, and horſes applied to theſe for turning the mill; which is often done where water cannot be had for that purpoſe.

The uſe of mills and mill-ſtones, according to Pauſanias, was firſt invented by Myla, ſon of Meleges, firſt king of Sparta; though Pliny attributes the invention of every thing belonging to bread and baking, to Ceres: Polydore Virgil was not able to diſcover the author of ſo uſeful a machine. It is doubted whether or not water-mills were known to the Romans, there being no mention made, in the Digeſt, but of mills turned by ſlaves and aſſes. Salmaſius, however, and Gothofred, will not allow water-mills to have been unknown to the ancient Romans, though they were not in ordinary uſe. Wind-mills are of much more modern invention; the firſt model of theſe was brought from Aſia into Europe in the time of the holy wars.

Mill is alſo uſed for any machine, which being moved by ſome external force, ſerves to give a violent impreſſion on things applied to it.

Mills, in this ſenſe, are machines of vaſt uſe in the manufactures, arts, and trades; for the making and preparing divers kinds of merchandizes. The principal are thoſe which follow.

Mill, *Colour.* Colours for the uſe of painters, paper-ſtainers, &c. are prepared, in the large way, by grinding them, either with oil or water, in mills worked formerly by horſes, but now frequently ſteam-engines are uſed for ſuch purpoſe in London. Theſe colour-mills conſiſt of a large toothed-wheel, or cog-wheel, worked by the horſes, or ſteam-engine, &c. which gives motion to ſeveral trundles and upright ſpindles of ſmall mill-ſtones placed round its circumference. The conſtruction and uſe of theſe will be readily comprehended from the following deſcription of a ſingle pair of ſtones to be worked by hand, *Plate* XXXV. *fig.* 1. The winch-handle A gives motion, by the labour of a man, to the ſpindle B and fly-wheel C, fixed thereon; and which alſo carries a ſmall ſpur-wheel D, having eighteen bevelled teeth, which work into thoſe of the crown-wheel E E, of twenty-ſix teeth, fixed upon the upright ſpindle F, working in a braſs collar at top, fixed to the piece of wood G, which is adjuſtable by means of the wedge H, ſo as to keep the teeth of the wheels properly in geer: the bottom of the ſpindle works in the end of a braſs ſcrew R, working in the bottom framing of the machine, and paſſing up through the centre of the lower ſtone, the turning of which ſcrew, occaſionally, adjuſts the diſtance of the ſtones, which are of the common conſtruction, exactly like thoſe for grinding flour, but ſmaller, each being ſixteen inches diameter and three inches thick. The upper ſtone I is ſupported on the upright ſpindle F by a ſhoulder and crow, the ſame as mill-ſtones in general; it has a hopper K affixed to it, and which revolves with it, into which the ſemi-fluid colours intended to be ground are put, and when ground they are protruded through a ſpout from the tub M, nineteen inches diameter, which contains the ſtones.

After the above proceſs, colours for the uſe of painters, &c. were ground by hand with oil or water, on a poliſhed marble ſlab with a pebble muller; but this proceſs being tedious and expenſive, as well as highly prejudicial to the health of the workman, Mr. James Rawlinſon of Derby, ſome years ago contrived a mill for this purpoſe, which is repreſented in *fig.* 2, a model of which he preſented to the Society of Arts in the Adelphi, London, in 1804. A is a roller or cylinder of black marble, truly formed and well poliſhed, 16½ inches diameter and 4½ inches broad; B is a concave muller, covering one-third of the roller, of the ſame kind of marble, well poliſhed, and fixed in the wooden caſe or frame *b*, which is hung on hinges at *i*, for uſe when the muller requires to be lifted off the cylinder. C is a crooked bar of iron, about an inch broad, moveable on a pin at *f*, in order to turn down out of the way when the muller is to be lifted off: near the end of this bar is a thumb-ſcrew *c*, whoſe end acts in a hole in the wooden caſe *b*, and ſerves to keep that and the muller ſteady, and to increaſe the preſſure of the muller as occaſion may require. D is a ſcraper or taker-off, made of a piece of clock-ſpring fixed in an iron frame K, in the manner of a frame-ſaw, and turning on centres *d d*, ſo that when in uſe the taker-off lies in an inclined poſition againſt the cylinder, and at other times is turned back out of the way. H is a plate ſet under the taker-off to catch the colour when ſufficiently ground, which ſtands upon a ſliding board that can occaſionally be drawn out, to remove any colour which may accidentally drop from the cylinder. F is a drawer under the mill for holding curriers' ſhavings, for cleaning the cylinder and muller, when a freſh colour is wanted to be ground. The colour, roughly ground in a large colour-mill above deſcribed, is applied in proper quantities, by means of a knife, to the front of the cylinder above the taker-off, and by means of the winch-handle G the mill is worked, until the colour, by paſſing between the revolving

ftone and muller, is fufficiently ground; when the taker-off D, which during the operation lay back, is turned againft the ftone, the winch-handle is turned the reverfe way for a few revolutions, in order to fcrape off the colour which falls into the difh H.

In the Philofophical Tranfactions, No. 87, a mill is defcribed as having been ufed by Dr. Langelot, for grinding leaf gold to powder, for the fanciful purpofe of preparing *Aurum potabile*: the principles of this mill were, fome years ago, found applicable to the grinding of dry indigo in Mr. Taylor's manufactory at Manchefter, and were alfo found by Mr. Rawlinfon, above mentioned, to be the beft adapted for finely pulverizing the dry colours intended to be ground with oil or water in his colour-mill. This fimple mill is reprefented in *fig.* 3, where L is a marble mortar, nicely formed and polifhed; M is a muller nearly in the form of a pear, having an iron axis fixed into its upper end, which is bent into the form of a crank at P to ferve as a handle for turning the muller: the axis is fixed, when in ufe, into two collars O, O, in beams of wood N N, fo as to revolve eafily and truly in the axis of the mortar. This muller is fhewn feparately at *fig.* 4, which fhews a flit that is made through it, almoft dividing it into two parts: this flit is of ufe in collecting the colour which is grinding, and bringing it continually under the muller. A circular board in two halves, with a centre-hole to fit the axis, is ufed to lay over the mortar, to prevent the duft of the colours from flying out, to wafte the fame and injure the health of the workmen. By means of the flat perforated weights R, on the top of the axis, any required preffure can be applied upon the muller.

For preferving the health of fuch colour-men and painters as ftill prefer the common ftone and muller for grinding their colours, M. Boulard, in the Journal de Phyfique, recommends an apparatus reprefented in *fig.* 5, wherein the ftone, and its table A B, is furrounded by a clofe-fided cafing of boards C, C, fitted to the floor of the room, and leaving a fpace of about $\frac{1}{10}$th of an inch wide all round the table fupporting the ftone; this is for emitting a current of frefh air, which is to be fupplied by a pipe D D extending from a hole in the floor under the cafe, to the outward air in fome moft convenient place. Over the ftone a glazed pyramid E E and metal tube F is fupported by the irons G and braces H, H, H, or by other more convenient means, fo that the pyramid E E projects, on all fides, about three inches beyond the ftone; and at a height above the fame no greater than is fufficient for the free admiffion of the workman's arms to work the muller, and with his pallet knife to fcrape together the colour when requifite, and which he will be able perfectly to fee to do, through the glafs in the frame, without inhaling the vapour from the colours, but which are to be made to afcend through the tube F, and pafs off into the open air through the tube M M, by means of a fmall ftove I I clofely jointed to the tubes F and G, which is to be kept burning during the hours of work, in order to produce a current between the pipes D and M, that may effectually carry off the contaminated air which has been in contact with the colours on the ftone, along with their effluvia. K reprefents the door of the fire-place, and L that of the afh-hole of the ftove, both contrived to fhut very clofe. In the pipe F a regifter N fhould be made for regulating the burning of the ftove, by the admiffion of more or lefs air thereto through the pipe F. If defirable, the clofe pipe F may be conducted into the fire-place of any ftove or fire in the apartments above, or it may even defcend by a proper curvature, fo as to admit of the ftove I I being placed on the ground, and applied to any ufeful purpofe, as the boiling of oil, or heating an adjoining room, &c.

MILL, *Cotton*. See MANUFACTURE *of Cotton*.

MILL, *Flood*, that fort of mill which is contrived for the purpofe of raifing water in order to difcharge it from fens, marfhes, and other fimilar kinds of land.

MILLS, *Forge*, turned by water, ferve to raife and let fall one or more huge hammers, to beat and form the iron into bars, anchors, and other maffive works. They are alfo called tilt-mills. See FORGE, IRON, and STEEL.

MILL, *Fulling*, is a water-mill which raifes and beats down large wooden piftons in proper veffels called *pools*, or *troughs*; in order to full, fcour, and cleanfe woollen ftuffs. See FULLING-*Mill*.

MILL, *Gunpowder*, is that ufed to pound and beat together the ingredients whereof gunpowder is compofed.

This is done in a kind of iron or brafs mortar, by means of iron peftles wrought by a wheel without fide the mill, turned by the water falling on it. See GUNPOWDER.

MILLS, *Leather*, are ufed to fcour and prepare with oil, the fkins of ftags, buffaloes, elks, bullocks, &c to make what they call *buff-leather*, for the ufe of the foldiery.

This is effected by means of feveral large piftons, rifing and falling on the fkins, in large wooden troughs, by means of a wheel without-fide, turned by the force of water.

MILLS, *Linen*, do not differ much from fulling-mills. Their ufe is, to fcour linens, after their having been firft cleanfed when taken out of the lixivium, or ley. Some of thefe go by water, and the generality by horfes.

MILLS, *Oil*, when turned by men, water, hand, or horfe, ferve to bruife or break the nuts, olives, and other fruits and grains, whofe juice is to be drawn, by expreffion, to make oil. See OIL.

MILL, *Paper*, a water-mill, furnifhed with engines containing cylinders furnifhed with teeth which cut and grind the rags or cloth in a kind of wooden trough; and thus, by reducing them to little pieces, turn them into a kind of pulp, by means of water conveyed into the troughs by a pipe for that purpofe. See PAPER.

MILL, *Sawing*, is a water-mill, ferving to faw feveral planks or boards at the fame time.

Thefe are frequent in France, efpecially in Dauphiné.

They were lately prohibited in England, where they were begun to be introduced, from a view to the ruin of the fawyers, which muft have enfued. See SAWING, alfo MACHINERY, *Block*.

There are alfo *filk* mills, for fpinning, throwing, and twifting filks; which are large round machines in form of turrets, five or fix feet high, and fix yards in diameter; which, being turned, either by the force of water or that of men, work at the fame time an infinity of bobbins faftened thereto, whereon the filk had been wound to be here fpun and twifted.

There are abundance of mills of this kind in France, efpecially about Lyons and Tours, fome of which are fo difpofed, as that three of them will go at the fame time, and by the fame wheel wrought by water or by ftrength of hand. That in the Hôpital de la Charité at Lyons, is wonderful, a fingle man working no lefs than 48 of thefe mills. See SILK, and WINDING *of Silk*.

MILL, *Stamping*. See STAMPING.

MILL, *Sugar*, is a machine that ferves to bruife the fugarcanes, and exprefs the liquor or juice contained therein. The fugar-mills are very curious contrivances. Of thefe there are four kinds, being turned either by water, wind, men, or horfes.

Thofe turned by the hand were firft in ufe; but they are now laid afide, as being an intolerable hardfhip on the poor

negroes who were doomed thereto, besides the slowness of their progress.

Wind-mills are the most modern: but they are yet somewhat rare, excepting in St. Christopher's and Barbadoes, and among the Portuguese. These make good dispatch, but have this inconvenience, that they are not easily stopped; which proves frequently fatal to the negroes who feed them. See Sugar.

Mills, *Tan* or *Bark*, wrought by water or horses, serve to cut certain barks into a coarser sort of powder, proper for the tanning of hides, &c.

Mills *for Sword blades* are likewise moved by water. They are frequent at Vienne, in Dauphiné. By working heavy hammers they forge those excellent sword-blades, called *blades of Vienne*.

The uses and operations of these several mills, more at large, see under Paper, Fulling, Sugars, &c.

Mill, *Threshing*, such a machine as is contrived for the purpose of threshing grain or other sorts of seed crops. See Threshing *Machine*.

Mill, in *Coinage*, is a machine used to prepare the laminæ, or plates of metal, and to give them proper thickness, hardness, and consistence, before they be struck, or stamped.

This machine has not been long known among us; but is of some standing in Germany. It consists of several wheels dented like those of clocks, &c. which move two cylinders of steel, between which the metal is passed to be brought to its proper thickness. It was first turned with water, since with horses. See Coinage.

Mill, in *Commerce*, a money of account in the United States of America; 1000 mills being = 100 cents = 10 deniers = a dollar.

Mill, among *Gold Wire Drawers*, is a little machine consisting of two cylinders of steel, serving to flatten the gold or silver wire, and reduce it into laminæ, or plates. See Gold *Wire*.

They have also mills to wind the gold wire or thread on the silk: these are composed of several rows of bobbins all turned at the same time.

Mill-*Reek*, in *Medicine*, an appellation given by the miners, employed at the Leadhills in Scotland, to those affections of the bowels, and of the nervous system, which are occasioned by the poison of the lead. The melting-houses, in which the operations are carried on, are called *mills*, because the bellows there are worked by water-wheels; and the *reek*, or smoke, arising from the melted lead, is believed to be the chief cause of the disease: whence the term *mill-reek* has been appropriated to the malady. See Essays and Obs. Phys. and Liter. vol. i. art. xxii. Edinburgh.

Mill-*Dams*, in *Rural Economy*, the basons which contain the water for supplying mills. A very firm way of making these in a quick or running sand, which is usually found a very troublesome circumstance in the making of them, is by laying the foundation with unslaked lime; which, by slaking among the sand, runs together into a hard stone, which gives a very firm and sure foundation. Piott's Staffordshire, p. 336.

Mill-*Holms*, a term applied to the low meadows, and other fields in the vicinity of mills, or watery places about mill-dams. The soils in these cases are generally of a good quality.

Mill-*Pool*, a stock or pond of water, by the force of which the motion of a water-mill is effected.

The dam of a mill-pool is raised much in the same manner as directed for *fish-ponds*; which see.

Mill-*Stones*, in *Rural Economy*, the prepared stones made use of in grinding grain and other substances, which are of different kinds, according to the purposes for which they are employed, but those chiefly used in grinding wheat into flour, were formerly imported from France, and termed *burrs*. Lately, however, stones proper for this use have been discovered in different parts of this kingdom, as in Wales and Scotland. In the first of these places they were found by Mr. Bowes, in a quarry which is "situated within the corporation liberties of Conway: the stone appears within a quarter of a mile of that town, and extends from east to west for the distance of two miles, appearing in most places upon the surface within that distance. Such an immense body of the stone has been left bare and exposed to view, that the industry of ages would scarcely lessen it. A deep chasm intervenes at the end of two miles; and, on examining the same line across this valley, he found the stone mixed up with various other fossil substances, to which it seems to bear no relation. In the next rise of mountains it resumes its quality, and takes a southerly direction, passing through a range of hills to the distance of two miles more, where the vein disappears. It is every where the highest stratum; and when disengaged from the quarry where now worked, it tumbles down the side of the mountain to the plain within five hundred yards of the shipping-place, where small vessels may lie safely in all weathers at a natural quay, completely calculated for this business." The quarry lies on the decline of a hill: the vein now is about eight yards wide; but he has reason to suppose it wider below. At the depth he has sunk, which is at least twenty-five feet, the stone mends in quality. When first taken from the quarry it is much softer and easier wrought into shape, than when exposed to the air: even a day makes a difference. The vein appears to him quite inexhaustible, and contains every variety of the stone, cellular, close, hard, or soft. The right in this tract of country has been presented to him, by Mr. Sneyd of Staffordshire, under the hope that he might be able to make this discovery, and carry it vigorously into effect, in which he has not been disappointed.

It would appear from the evidence sent to the Society for the Encouragement of Arts, &c. that the stones raised from this quarry are capable of being employed in most cases where those imported from France have been in use, and that the stone, from its external appearance, seems to be constituted of quartz and cherts.

And in the latter of the above situations stones fit for this use were discovered by James Brownhill, miller, "who, when the late unfortunate war had rendered the getting of the French burr extremely difficult, as he was passing by the great basaltic rock of the Abbey Craig, near Stirling, examined the texture of several masses of the stones; and found one species, which appeared to him fit for the grinding of wheat, and brought home a sample of them, which he shewed to Mr. Alexander Ball, agent of the Alloa Mills, who agreed to make trial of a pair. They were built under his direction in the same manner as the French burr; and, on their being put to work, gave such satisfaction to the customers of the mills, as induced the Alloa Mill company to have another pair built, and totally lay aside the French burr mill-stones." It is suggested, that "the French burr stones are so porous, as to make it necessary to fill up the cavities with a preparation of alum: this considerable expence is saved by the uniform texture of the basaltes; and their superior excellence is so apparent, that upwards of 60 pair are now at work in several parts of the kingdom, and the demand for them is daily increasing." In addition it is stated, that "the basaltes mill-stones are not only excellent for manufacturing of flour, but for all kind of grist. The distillers give them a decided preference, and they grind oats

in a very complete ſtyle, as the meal is returned quite free of ſand, which is a great deſideratum for thoſe places where oat bread is in uſe. The diſcoverer of this uſe of the baſaltes, builds mill-ſtones of all ſizes on moderate terms, and is careful, from his experience as a miller, to build them of ſuch a grain as is moſt ſuitable for the particular purpoſes for which they are intended.

The following remarks are offered by Mr. Ferguſon on the ſize and velocity of mill-ſtones. The diameter of the upper ſtone is generally about ſix feet, the lower ſtone about an inch more; and the upper ſtone, when new, contains about 22½ cubic feet, which weighs ſomewhat more than 19,000 pounds. A ſtone of this diameter ought never to go more than 60 times round in a minute; for if it turns faſter, it will heat the meal. But according to Mr. Imiſon, the mill-ſtone ſhould turn twice round in a ſecond of time, and ſhould only be four feet and a half in diameter. It may probably be imagined, that the meal will be much heated by ſuch a rapid motion as he has recommended, but the effect is counteracted by diminiſhing the ſize of the mill-ſtone from ſix feet to four and a half. The velocity of the circumference of the ſmall mill-ſtone moving twice round in a ſecond, is only one-third greater than the velocity of the large mill-ſtone moving once round in a ſecond.

It may be noticed, that in the former of the above quarries mill-ſtones are raiſed which are of much larger ſizes than the French burrs, which may probably be an advantage in ſome caſes.

The modes of preparing mill-ſtones for the purpoſe of grinding have been deſcribed already, and *fig.* 6. of *Plate* XXXV. repreſents the ſurface of the under grinding mill-ſtone, the way of laying out the wads or channels: the wooden buſh is fixed into the hole in the middle, in which the upper end of the iron ſpindle turns round; and the caſe or hoops that ſurround the upper one, which ought to be two inches clear of the ſtone all round its circumference. B ſhews the upper grinding mill-ſtone, and iron croſs or ryrd in its middle, in the centre of which is a ſquare hole that takes in a ſquare on the top of the iron ſpindle, to carry the mill-ſtone round: when the working ſides or faces of the mill-ſtones are laid uppermoſt, the wads muſt lie in the ſame direction in both, that when the upper ſtone is turned over, and its ſurface laid on the under one, then the channels croſs each other, which aſſiſts in grinding and throwing out the flour; the wads are alſo laid out according to the way that the upper ſtone revolves. In theſe the running mill-ſtone is ſuppoſed to turn *ſunways*, or what is called a right-handed mill; but if the ſtone revolves the other way, the channels muſt be cut the reverſe of this, and then it is termed a left-handed mill. See MILL.

The mill-ſtones which we find preſerved from ancient times, are all ſmall, and very different from thoſe in uſe at preſent. Thoreſby mentions two or three ſuch found in England, among other Roman antiquities, which were but twenty inches broad; and there is great reaſon to believe that the Romans, as well as the Egyptians of old, and the ancient Jews, did not employ horſes, or wind, or water, as we do, to turn their mills, but made their ſlaves and captives of war do this laborious work; they were in this ſervice placed behind theſe mill-ſtones, and puſhed them on with all their force.—Sampſon, when a priſoner to the Philiſtines, was treated no better, but was condemned to the mill-ſtone, in his priſon. The runner, or looſe mill-ſtone, in this ſort of grinding, was uſually very heavy for its ſize, being as thick as broad. This is the mill-ſtone which it is expreſsly prohibited in Scripture to take in pledge, as lying looſe it was more eaſily removed. The Talmudiſts have a ſtory, that the Chaldæans made the young men of the captivity carry mill-ſtones with them to Babylon, where there ſeems to have been a ſcarcity at that time; and hence, probably, their paraphraſe renders the text "have borne the mills, or mill-ſtones;" which might thus be true in a literal ſenſe. They have alſo a proverbial expreſſion of a man with a mill-ſtone about his neck; which they uſe to expreſs a man under the ſevereſt weight of affliction. This alſo plainly refers to this ſmall ſort of ſtones.

MILL-*Work*. Under this head we intend to treat of the parts and mechanical contrivances uſed in mills. Under the article MACHINERY, the reader will find obſervations of a ſimilar nature to thoſe of the preſent article, but applied to ſmaller and more delicate machines than thoſe which are uſually denominated mills.

The object of this article will therefore be, to give a general account of the moſt important pieces of mill-work, as cog-wheels, ſhafts, bearings, &c.; which parts being common to mills of all kinds, would, if minutely deſcribed under every head where they are employed, introduce a great many needleſs repetitions.

The different firſt movers of mills will be treated of, and deſcribed under their ſeveral heads of STEAM-*Engine*, WATER-*Wheels*, and WIND-*Mill*; and the acting machines of ſeveral kinds of mills, as clay-mill, grinding-mill, under CUTLERY; fulling-mill, flour-mill, iron-mill, under MANUFACTURE *of Iron*; oil-mill, cotton-mill, under MANUFACTURE *of Cotton*; rolling-mill, ſpinning-mill, ſilk-mill, thraſhing-mill, water-mill, ſawing-mill, under MACHINERY *for manufacturing Ships' Blocks at Portſmouth*; TILT *Mill*, &c. &c.

Cog-wheels are the moſt important and numerous parts of mill-work, few mills being without them, to modify the direction, and adapt the power of the firſt mover, which actuates the mill, to the working point, or the machine which performs the operations the mill is intended for. Moſt mills contain ſeveral different kinds of machines, or operative parts, all deriving their motions from the ſame ſource, or firſt mover. Thus, a flour-mill contains ſtones for grinding; dreſſing machines for ſifting the flour; ſack tackle, for drawing up the ſacks, &c.; all which are moved by the ſame firſt mover as a water-wheel, wind-mill, ſteam-engine, or horſe-wheel. But each of theſe machines requires to be moved with a different velocity to perform its work in the beſt manner; and it is the object of the mill-work to obtain theſe different velocities from the ſame firſt mover, chiefly by the means of wheels; which, therefore, from their importance, deſerve the firſt notice. There are a variety of cog-wheels, as ſpur-wheels, (or *gear* in the technical phraſe,) bevil-wheels, face-wheels or crown-wheels, pinions or nuts, trundles or lanterns; with a variety of other names which are local, but have the ſame ſignification with ſome of the above.

Spur-wheels are thoſe in which the teeth project from the periphery of the wheel, in the direction of radials (ſee *Plate* I. *fig.* 1. *of Mill work*): they are ſo called, from the reſemblance to the rowel of a ſpur. A ſpur-wheel is uſed to communicate motion by its teeth to another, ſituated in the ſame plane; conſequently, the axes of the two are parallel to each other. The ſpur-wheel, at other times, works with *a pinion*, or nut (ſee *fig.* 2.), which is in fact a ſpur-wheel of ſmall ſize: at other times with a *trundle* or *lantern*. This is a pinion of peculiar conſtruction, conſiſting of two circular boards A, A, (*fig.* 3.) fixed, at ſome diſtance apart, upon its axis of motion or ſhaft B B, and united by a number of cylindrical pins *a*, *a*, called ſtaves, or rounds, which are arranged in a circle, and fixed parallel to the axis of the trundle between the two boards of it. The teeth of the wheel

act upon these rounds to give motion to the trundle; the rounds, therefore, must be the same pitch or distance asunder as the cogs of the wheel. The number of the rounds of the trundle of course determine its diameter. Trundles have of late years fallen into disuse among mill-wrights, cast iron pinions being found much more preferable: they were sometimes used to work with spur-wheels, but more commonly with

Face-wheels, see *fig*. 4. In these, the teeth or cogs are fixed perpendicularly to the plane of the wheel, parallel, therefore, to its axis: they were used to work with another similar wheel, or with a trundle with a spur-wheel, or with a pinion, when the two axes were required to be perpendicular to each other, as shewn in *figs*. 3 and 4.

The crown or face-wheel has of late years been almost wholly superseded by bevil-wheels, which, in all situations where a wheel is required to turn another in a direction perpendicular or inclined to itself, are found vastly superior.

Bevilled or *Mitre-wheels*, see *fig*. 5. of the plate, have their teeth formed upon a conical surface, the angle of the cone being the same as the angle the axes C, D, of the two wheels A, B, make with each other. The introduction of this class of wheels into machinery is a very essential improvement, which has been wholly made within these thirty years. Bevil-wheels are of course always used to work with others of the same kind.

The manner of setting out the teeth of cog-wheels, in such a form that they shall act in the most equable manner upon each other, and with the least friction, has been a subject of much investigation among mathematicians and theoretic mechanics; but the practice and observation of the mill-wrights have produced a method of forming cog-wheels, which answers nearly, if not fully as well in practice, as the geometrical curves which theory has pointed out to be the most proper. This they have effected by making the teeth of the modern wheels extremely small and numerous. In this case, the time of action in each pair of teeth is so small, that the form of them becomes comparatively of slight importance; and the practical method of the mill-wrights (using arcs of circles for the curves) approximates so nearly to the truth, that the difference is of no consequence: and this method is the best, because it so easily gives the means of forming all the cogs exactly alike, and precisely the same distance asunder, which, by the application of any other curve than the circle, is not so easy. The method, which is extremely simple, is explained by *fig*. 1. The wheel being made, and the cogs fixed in much larger than they are intended to be, a circle, *a a*, is described round the face of the rough cogs upon its *pitch diameter*, that is, the geometrical diameter, or acting line of the cogs; so that when the two wheels are at work together, the pitch circles, *a*, *a*, of the two are in contact. Another circle, *b b*, is described within the pitch circle for the bottom of the teeth, and a third, *d d*, without it, for the extremities. After these preparations, the pitch circle is accurately divided into the number which the wheel is intended to have: a pair of compasses are then opened out to the extent of one and a quarter of these divisions, and with this radius arcs are struck on each side of every division, from the pitch line *a* to the outward circle *d d*. Thus, the point of the compasses being set in the division *e*, the curve *f g* on one side of the cog, and *n o* on one side of the other, are described; then the point of the compasses being set on the adjacent division *k*, the curve *l m* is described. This completes the curved portion of the cogs *e*, and this being done all round completes every tooth: the remaining portion of the cog within the pitch circle, *a*, is bounded by two straight lines drawn from the points *g* and *m* towards the centre; this being done to the cogs all round, the wheel is set out and the cogs, being dressed or cut down to the lines, will be formed ready for work, every cog being of the same breadth; and the space between every one and its neighbour is exactly equal to the breadth, provided the compasses are opened to the extent of one division and a quarter, as first described.

Many different methods of forming teeth have been proposed, among them the following: Let the tooth *a* (*fig*. 6.) press on the tooth *b* in the point C; and draw the line F C D E perpendicular to the touching surfaces in the point C: draw A F, B E, perpendicular to F E, and let F E cut the line A B in D. It is plain from the common principles of mechanics, that if the line F E, drawn in the manner now described, always pass through the same point D, whatever may be the situation of the acting teeth, the mutual action of the wheels will always be the same. It will be the same as if the arm A D acted on the arm B D. In the treatises on the constructions of mills, and other works of this kind, are many instructions for the formation of the teeth of wheels; and almost every noted mill-wright has his own nostrums. Most of them are egregiously faulty in respect to mechanical principle. Indeed, they are little else than instructions how to make teeth clear each other without sticking. Dr. Hooke was, we think, the first who investigated the form of teeth which procured this constant action between the wheels; and in a very ingenious dissertation, published among the Memoirs of the Academy of Sciences at Paris, 1668, this gentleman shews that this will be ensured by forming the teeth into epicycloids. Mr. Camus, of the same academy, has published an elaborate dissertation on the same subject, in which he prosecutes the principles of M. De la Hire, and applies it to all the varieties of cases which can occur in practice. There is no doubt as to the goodness of the principle, and it has another excellent property, "that the mutual action of the teeth is absolutely without any friction." The one tooth only applies itself to the other, and rolls on it, but does not slide or rub in the slightest degree. This makes them last long, or rather does not allow them to wear in the least. But the construction is subject to a limitation which must not be neglected. The teeth must be so made, that the curved part of the tooth *b*, is acted on by a flat part of the tooth *a*, till it comes to the line A B in the course of its action; after which the curved part of *a* acts on a flat part of *b*, or the whole action of *a* on *b* is either completed, or only begins at the line A B, joining the centres of the wheels.

Another form of the teeth secures the perfect uniformity of action without this limitation, which requires very nice execution. Let the teeth of each wheel be formed by evolving its circumference; that is, let the acting face G C H of the tooth *a* have the form of a curve traced by the extremity of the thread F C, unlapped from the circumference. In like manner, let the acting face of the tooth *b* be formed by unlapping a thread from its circumference. It is evident that the line F C E, which is drawn perpendicularly to the touching surfaces in the point C, is just the direction or position of the evolving threads by which the two acting faces are formed. This line must, therefore, be the common tangent to the two circles or circumferences of the wheels, and will, therefore, always cut the line A B in the same point D. This form allows the teeth to act on each other through the whole extent of the line F C E, and, therefore, will admit of several teeth to be acting at the same time; (twice the number that can be admitted in Mr. De la Hire's method.) This, by dividing the pressure among several teeth, diminishes its quantity on any one of them, and, therefore, diminishes the dents or impressions which they unavoidably

make on each other. It is not altogether free from fliding or friction, but the whole of it can hardly be faid to be fenfible. The whole fide of a tooth three inches long, belonging to a wheel of ten feet diameter, acting on the tooth of a wheel of two feet diameter, does not amount to $\frac{1}{70}$th of an inch, a quantity altogether infignificant. Conical wheels, or bevilled gear, may be confidered as confifting of two cones rolling on the furfaces of each other: let B and C, (*fig.* 7.) be the bafes of two cones turning on their centres, having teeth cut on them diverging from the apex A to the bafes B and C. Thefe teeth will work freely into one another from the apex A to the bafes B and C, when turned round; but the teeth near the point of the cone being fmall and of little ufe, may be cut off at G and H. Thefe teeth may be made of any breadth, according to the ftrefs they are intended to bear; and this is of vaft importance, becaufe by this method they may be made to overcome a much greater refiftance, and work fmoother than a face-wheel and trundle of the common form. Befides, thefe kind of wheels are of fingular ufe to communicate motion in any direction, or to any part of a building, with lefs trouble and friction than wheels of any other conftruction.

We fhall now venture fome remarks upon the manner of conftructing wheel-work. Cog-wheels were formerly made of wood, and fome are ftill conftructed of that material; but of late years caft-iron wheels have been fubftituted, and found much fuperior in ftrength, accuracy, and durability. Wooden wheels are framed together in fegments ufually of three thickneffes, to break the joints upon each other. (See *fig.* 1.) The middle thicknefs is made in fix or eight pieces, and left on the infide with ftraight fides, *x*, *x*, into which the arms are fitted, and bolted againft it. On each fide this middle thicknefs, another is (X X, *fig.* 1.) placed with break joints, and all the three are bolted together to make a folid rim, in which the cogs are to be fixed by mortifes, the tenons or tails of the cog being held in their places by a pin driven through each. The arms of wooden wheels are made in different ways; fometimes they are mortifed through the fhaft, and the ends are notched in the middle of the fides of the octagonal pieces *x*, *x*, and laying againft the face of them behind, are bolted to them to make all faft. This manner of uniting the arms with the rim is fhewn at *l* (*fig.* 4.); but this method is not the beft, becaufe the mortifes weaken the fhaft very materially, and it is difficult to get fuch a wheel off if ever it is required, on a failure of the fhaft, &c. On this account, the method called clafp arms is much preferable: it is fhewn in *fig.* 1. Four arms E E, F F, are ufed, which are halved into each other, and form a frame as in the figure, leaving a fquare opening in the centre, and holding the rim of the wheel by their ends, which are bolted to the middle thicknefs of the rim, as fhewn in *fig.* 4. To fit on fuch a wheel as this, the fhaft is made up to a fquare, by fixing pieces of wood upon its fides; and the wheel being hung upon this, is made faft by wooden wedges driven in all round, the fquare formed between the arms being rather larger than the fhaft, by which means the wheel can be adjufted to come quite true by the wedging. Face-wheels, like *fig.* 4, have fometimes ftays or braces proceeding from the back of the rim to fome diftance along the fhaft, where they are received in mortifes, as fhewn by the dotted lines: thefe make the wheel exceedingly ftrong, and keep it very ftiff in the fquare upon its axis, which is very neceffary, as the action of the teeth of a face-wheel meeting a trundle, is to throw the wheel back upon its fhaft, which tendency thefe ftays effectually counteract. At other times, two fets of clafp arms are ufed for the fame end, one bolted on each fide of the middle thicknefs of the wheel, by the fame bolts which pafs through both, as well as the wheel, and unite the two fets like one, but of confiderable depth, fo that the wedging will have a greater effect to keep the wheel in the fquare. Small wheels are frequently made of plank, folid, without any arms. In this cafe the middle thicknefs is made of four pieces, leaving a fquare hole between them, and they are kept together by a circular ring of fegments, bolted on at each fide all round, and the joints overlapped. The conftruction of trundles (*fig.* 4.) has been fufficiently explained, except that they ufually have an iron hoop fitted round the circular boards to prevent them from fplitting: indeed many large face-wheels have the fame. Small pinions are made out of one block of wood, and the cogs are fitted into it much in the fame manner as the fpokes are let into the nave of a coach-wheel. Iron-wheels either have the cogs caft in the fame folid piece with the rim, or mortifes are left in the caftings for the reception of wooden cogs, as thefe are found to work much better. The wheel and its arms are fometimes caft in one piece, but for large wheels the rim and its arms are formed in two feparate pieces and fcrewed together. The reafon of this is, that in cafting a large and extended piece of iron, it frequently happens that fome parts will cool in the mould, and become folid before the others: confequently, from their contraction, thefe parts will be fhorter than others which have retained their heat and fluidity longer. This circumftance happening to the arms of a wheel, will either warp the rim out of a true circle, or fet the metal of one part upon a ftrain againft another, fo that the flighteft blow or jar will caufe them to fnap in fuch parts. All this danger is avoided by making them in feparate pieces, as in *fig.* 8: the end of each arm, as A B, has a flat expanded part, which lays againft a proper focket withinfide of the rim C D, and is bolted to it. One-half of this wheel is delineated, with wooden cogs fitted in, at C D; and the other half, F F, fhews the form of a rim, where the cogs and the arms *e f* are caft all in one piece. In the latter cafe the rim has a rib *g* withinfide it for ftrength, in the fame manner as all the arms have, and which is evidently fhewn by the figure. In fome fituations it is neceffary to fix wheels upon long fhafts while they are in their places, and cannot conveniently be taken down: in this cafe fuch wheels may be made in two halves bolted together. *Fig.* 9. is drawn as if it were two halves of different kinds put together in this manner; the joint being up the middle of the arms L, L, and the connecting bolts are plainly fhewn. By this method one wooden pattern, if very accurately made, will ferve for cafting both halves of the wheel. Cog-wheels are found to work with leaft friction, wear, or noife. When one has wooden, and the other iron cogs, dreffed exceedingly fmooth and true, the fmall wheel is ufually made with the iron teeth, and the large one with the wooden ones. When fuch wheels are firft fet to work, the cogs are fmeared with black lead mixed with tallow: this gives them a gloffy furface, which greatly diminifhes the friction. Hornbeam is found to be the beft wood for the cogs, as it is not liable to fplit or fplinter away by long wear. The cogs are held in by a pin driven through the tenon or tail, withinfide the rim of the wheel. The wooden cogs are dreffed by chiffels to the marks fet out, in the fame manner as wooden wheels; but the iron cogs are firft chipped with a cold chiffel and hammer, and then filed true. The great labour of doing this induced Meffrs. Boulton and Watts, fome years ago, to erect machinery for dreffing cogs. The wheel was provided with apparatus to hold it faft at the feveral divifions, and a ftrong flider, with a chiffel fixed in it, was forced between the rough cogs by the revolution of a camm or heart,

with a sufficient power to cut away a shaving, and form the cog perfectly at twice repeating the operation. Some mechanics dispute the propriety of dressing iron cogs at all; they say, that the exterior surface of the castings have a kind of case-hardening, which is removed by the dressing, and a softer substance of metal exposed for the acting surfaces. This is true, and the objection would have its full force, if it were possible to make castings of wheels perfectly true in the circle, and all the cogs precisely the same size: but as the present state of the founder's art cannot insure this, it is best to chip and file the cogs; accuracy in the form of the teeth being a superior consideration to any quality of their substance. The wheel being made in either of these methods, must next be fixed, or *hung*, upon its shaft. Wheels are generally fixed fast upon their shafts or axles before their teeth are set out; or, if this is not convenient, they are fixed on a temporary spindle to set them out. When the wheel is made of wood, it is fixed upon the shaft, or a temporary axis, and turned round upon its pivots, while a chissel is laid on some fixed support to cut or turn its circumference to a true circle, or else to make a mark to which its rim may be reduced all round. The circumference is then divided, and mortises cut out for every cog; and when these are fixed in they are much larger than they are intended to be, that they may be set out, as above directed, and reduced to their true figure, without absolutely depending upon the accuracy of the mortises which receive them. Iron wheels are, as before-mentioned, treated in a different manner, being cast in the impression of a truly circular pattern made of wood; the cogs cast solid, with the rim or else mortises left all round for the reception of the wooden cogs: in either case the rim is a true circle, and must be fixed upon the shaft exactly by its centre, instead of forming the circumference to the centre, as in the wooden wheel. To do this, the centre hole through the iron wheel is made much larger than the shaft which is to go through it, and the space all round is filled up by iron wedges driven in; so that by means of these the wheel can be fixed exactly true in the centre (or in the round), and also in the flat that is truly perpendicular to the axis. The manner of arranging the wedges is shewn in *fig.* 8, where eight wedges are shewn by *a, a, a, a,* &c. round the shaft R. It is needless to explain how the wheel can, by means of these, be set exactly true, when it is found by turning round upon the pivots of its shaft that any one side of the circumference is farther from the centre than another. For the purpose of setting it square upon the shaft, each wedge-hole is provided with two wedges, one driven in from each side of the wheel, the two laying over each other in the notch or hole in the manner shewn at G. Thus, by gently driving one in, and the other a little outwards, the wheel may be very correctly rectified, if it has any deviation from the perpendicular. This is the usual manner of hanging wheels, and for large wheels it is the only applicable method. *Plate* II. *figs.* 9 and 10, is a far superior plan for such iron wheels as are not too large or heavy to be turned in a lathe upon a chuck, so that the centre is exposed, and may be bored through with a truly circular hole, and rather conical: of course the wheel is fixed upon the chuck, so that its circumference runs truly; and at the same time the centre is bored, the pitch circle is described upon the cogs, and sometimes the ends of the cogs are turned to reduce them to a true circle, and also the sides, that they may be exactly flat: for, as we have before observed, iron wheels, however true their teeth may be cast, should always have their cogs rather too large, and then be set out and dressed, by chisseling and filing, to make them perfectly correct to the lines thus described. But to return to *fig.* 9; the wheel being prepared, and its centre bored out, the shaft is turned, as usual, to form its pivots, and, at the same time, the part which is to receive the wheel is turned conical, to fit the hole through the wheel, which being jambed thereon will certainly be true at once: and to prevent it from slipping round upon its axis various means are in use; sometimes a mortise is formed through the shaft A, at the small part of the cone, and a wedge *r* driven through, which is received in notches at the sides of the hole through the central part of the wheel, so that it holds the wheel from turning round on the shaft, at the same time that it drives it hard, and fixes it upon the conical fitting. Another method is to cut a channel along the conical part of the shaft parallel to the axis of it, and another similar one withinside of the hole through the wheel; then a fillet or feather of iron *s*, (*fig.* 10.) being inserted into the two grooves, effectually prevents the wheel from turning, unless the strain is so great as to cut the feather in two through its whole length, which is easily prevented by making it of a proper thickness. Another method of fixing a wheel is to have a flaunch, or flat shoulder, formed upon the shaft, and the wheel is drawn up against this by two, three, or four screw-bolts going through it, and also through the central part of the wheel, parallel to its axis. This plan is neither so neat, simple, nor strong as the former. When a wheel is required to be sometimes disengaged from its axis, the conical or cylindrical fitting is very convenient. In this case, the wheel should fit up against a flat shoulder, as *a*, in *fig.* 11, and at the opposite side should have a collet, or ring *b*, to confine it, and kept up by a key going through to the shaft R. In this way the wheel will slip round freely upon its axis, and communicate no motion thereto, though it is in constant motion itself: but when they are required to be connected, a locking bayonet, or clutch-box, is used. These pieces of mechanism are constructed in different forms; one of them is shewn in the figure. Strong arms A, A, are fixed fast on the shaft R, just before the wheel either by a circular fitting with a fillet, by a square, or they may be cast with it. Through the extremities of these arms holes are drilled to receive the shanks *f, f*, of the locking bayonet, which are fixed by nuts fast to an arm D, very nearly similar to A A, but it slides on the shaft, and has a central part *g*, with a circular groove round it, in the manner of a pulley, and a fork embracing the central piece in this groove gives the means of sliding the bayonets *f f*, and D, upon the shaft, so that the points of its shanks intercept the arms of the wheel, so as to carry it round with them and the shaft; but when the points of *f f* are drawn back clear of the arms of the wheel, it slips round freely upon the shaft. The clutch-box is rather different from this; it is a piece fitted upon the shaft with a fillet, so that it cannot slip round, but will slide endways upon it. The end of the piece is formed with several notches, or indentations across its face, which meet similar indentations in the face of the central part of the wheel, and thus unites the wheel and the shaft when the clutch is slid up to it; but the wheel is disengaged when the clutch is drawn from it. The construction of *bearings* for the support of pivots at the ends of shafts or spindles, is a matter of great importance in mill-work. The old kind of bearing called brasses is shewn in *fig.* 12. A lump of brass *a*, with a semicircular notch in it, was let into the piece of timber A, which was to support it; and two screw-bolts *b, b*, were fixed through the timber, being half received in notches formed in the sides or ends of the brass *a*: the upper brass, *b*, was exactly similar to the lower, and over it a plate of iron, *d*, was placed, with two holes through it to receive the two bolts *b, b*, and keep

them together: the nuts *c, c*, upon the tops of the bolts confined the upper brafs down, and made all faft and tight. This kind of brafs is not fufficiently ftrong or fteady for all purpofes, and, therefore, the bearing fhewn in *fig.* 13. has taken its place: in this, *aa* is a caft-iron plate, which is held by two or more bolts *r, r*, down upon the timber or framing of the mill: this piece of caft-iron has two pieces *b, b.* rifing up from it, between which a piece of brafs, *l*, is bedded, and has a femicircular notch in it. Another fimilar piece of brafs is fixed into the caft-iron cap-piece B, which is fitted into the fpace between the two pieces *b, b*, and is drawn down by nuts upon the two bolts *c, c*. The braffes are prevented from getting out fideways by fmall fillets projecting from the middle of them, which are received into proper notches in the caft-iron work. In the fame manner the cap B is fitted between the pieces *b, b*, with a tongue or fillet, and groove, fo that it cannot deviate fideways, and then the bolts have only to draw the braffes down together. Sometimes a bearing of this kind is fitted up, fo that it is adjuftable in its pofition a little to adjuft two wheels to work accurately with each other, or for other purpofes where nicety is required. In this cafe, an iron plate, D, is bolted down to the framing, and the bearing, *a a*, lays upon it, the fame bolts *r, r*, going through both, and alfo through the framing beneath; but the holes through which they pafs in the piece *a a* are oblong, to admit the whole bearing being adjufted fideways. This is done by two wedges *o, o*, inferted at the ends of the piece *a a*, between the two ends of D, which rife up for the purpofe, as at *n n*. The bearing refts upon two wedges at *g, g*, and is drawn down upon them by the bolts *r, r*. By thefe two wedges it can be raifed up at pleafure, and by the other two, *o, o*, at the ends, it can be adjufted endways to fet the bearing in the exact pofition required; and the bolts *r, r*, when fcrewed faft, hold all tight. The beft way to make the interior furface of the braffes for a bearing exactly true, is to have them caft folid, that is, the two halves of the brafs in one, with a notch which very nearly, but not quite feparates them. In this ftate it can be chucked in a chuck-lathe, and the infide bored or turned out true: then it may be fawn in two halves, and put into its place, to which it fhould have been previoufly fitted. Sometimes the bearing is all fitted together and fcrewed down in its place, and a borer is ufed to bore or broach out the hole for the braffes, the fame as is employed to bore pump barrels. Brafs is found, by experience, to be the beft fubftance to form bearings for a caft-iron gudgeon, having the leaft friction, and, confequently, leaft wear, of any other fubftance which can be ufed. To diminifh this friction ftill farther, friction-wheels are fometimes ufed. The manner of conftructing thefe, when merely required to fupport a gudgeon, leaving its own weight to keep it down in its place upon them, is fhewn in *fig.* 14. Here A A is an iron plate, which is to be bolted down upon the framing: it has holes through it to receive the friction-wheels B, B, and fupports bearings *a, a*, for their pivots raifed up to a proper height, and provided with fockets for braffes, in which the pivots of the friction-wheels are to lie. The two friction-wheels B, B, as is evident, lie by the fide of each other, and the gudgeon, D, of the fhaft they are to bear lies upon and between them, fo that when it turns round it rolls upon them, or rather, their circumferences move with it, and, confequently, the pivots of the friction-wheels move fo flowly, as to diminifh the friction very materially, the proportion depending on the relation between the diameters of the wheels B and the gudgeon D. This is not the beft kind of friction-wheels, though the fimpleft. *Plate* II. *fig.* 15. *of Mill-work*, contains a view of another kind, called friction-rollers: here A A is an iron plate bolted down to the framing, and an iron ring, B, rifes up from it, all caft in one piece. The interior furface of this ring is turned in the lathe with the greateft accuracy, and the pivot or gudgeon C, which is alfo turned true, refts in the centre thereof, being fupported by fix rollers *a, a*, &c. arranged at equal diftances round it, and of fuch a diameter as to exactly fill up the fpace all round between the gudgeon and the ring. The rollers, it is evident, muft be made all of one exact diameter, and extremely true, and they muft fill up the fpace: then the gudgeon being turned round acts upon thefe rollers, and turns them round alfo at the fame time by this motion. As they have no fixed centre, they alfo roll round within the ring B, in the fame direction as the motion of the gudgeon, but with a very flow motion, which will be in proportion to the relative diameters of the gudgeon C and the ring B. By this means nearly all the friction is avoided, nothing like the fliding of a gudgeon round upon its bearing taking place here; it is all rolling of one furface upon another: and as the contact of two cylinders, fuppofing them hard, is but a line, the friction, or more properly adhefion, is exceedingly fmall; and at the fame time that the gudgeon is as ftrongly fupported as poffible: but this depends upon the hardnefs of the matter of the gudgeon, the rollers, and the ring B. If the ring and gudgeon are made of hard caft iron, and the rollers of fteel at a fpring temper, it will act extremely well, though the ftrain or weight upon the rollers be very great. For light ftrains fofter fubftances might be ufed, but not to fo good an effect.

The manner of keeping all the rollers at their relative diftances from each other, in the ring B, that they may not run againft each other, is yet to be explained. Each roller, as fhewn at *x*, has a groove turned in it in the middle of its length, fo as to reduce it to a fmall neck in the centre: then an iron ring, L, is provided, which has fix holes drilled in it, in the proper pofitions for the centres of the rollers, that is at equal diftances round a circle, which is as much lefs than the ring E as the diameter of the rollers, or the fame quantity larger than the diameter of the gudgeon C. Thefe holes are made to fit the fmall neck in the centre of the rollers, and to get them in, the holes are cut open from the outfide of the ring, fo as to become notches; then the rollers being put into them, are all in one clufter, and in this ftate are introduced into the ring E. They will now be kept at their proper diftances afunder, and when the gudgeon C is introduced between them, they will all take their proper places, and lie truly parallel. It is to be obferved that the holes or notches in the ring L, do not exactly fit the necks of the rollers, which have therefore confiderable play, and but very little friction, for it is not effential to keeping the rollers at their relative diftances that this ring fhould be ufed, but it will prevent the danger of their getting wrong by accident. To prevent any duft or dirt getting in, which would completely deftroy the action of this ingenious mechanifm, a circular iron plate is fitted into the ring B, on each fide, and both are fixed by fmall fcrews going through the ring. One of the plates N muft of courfe have a hole through the middle, to admit the gudgeon. The joints of thefe plates fhould be water tight, and then a quantity of oil being poured in, will remain in the bottom of the ring B, and every roller, as it paffes, will be kept oiled; though this is no ways neceffary to their action. The end plate, which is not perforated, will make a ftop to prevent the gudgeon moving endways, and the two plates will keep the rollers from fhifting their pofition on end; but to prevent friction, if ever they come in contact, the ends of the roller fhould be rather convex, as fhewn at *x*, that they may touch in the

centre rather than the outfides; but they will never bear hard againft the plate, having no drift that way.

A patent was taken out for thefe friction rollers many years ago, and a large manufactory was eftablifhed for making them for various purpofes, as carriage and waggon-wheels, the gudgeons of heavy water-wheels, &c.: they were found to poffefs great advantages, having fcarcely any fenfible friction when in motion, but were liable to get out of order chiefly from the entrance of duft, which occafioned the rollers to wear out of the round more on one fide than the others; and if once by this accident the rollers ftood ftill for an inftant, the gudgeon wore a flat place in the two rollers beneath it, and they would never run round again: a very little time would wear this flat fide fo deep as to ftop the rollers, becaufe of the very fmall furfaces in contact with the gudgeons. For delicate purpofes, where hardened fteel can be employed for all the rollers and the ring, they are a moft admirable contrivance, and the above objections will then apply very flightly; but, as before mentioned, their perfection and durability will ultimately depend upon the hardnefs of the fubftances employed.

Fig. 16. reprefents a fuit of friction rollers for fupporting the weight of a heavy vertical fhaft, as a horfe-wheel, a horizontal wind-mill, a capftan fugar-mill, &c. A A is a plate fupporting the weight of the fhaft; it has a conical eminence upon it, and a hole in the centre of this, which exactly fits the pivot or gudgeon *c*, at the bottom of the fhaft R: upon this gudgeon a conical plate B is formed, exactly of the fame fhape and fize as the conical part of the plate A, and between thefe two plates three or four rollers *a*, *a*, are fituated, and bear the weight of the fhaft R, or whatever preffes upon the plate B. The rollers are kept at proper diftances afunder by a ring, fhewn feparate at L, with three arms, *n*, projecting from it, which being formed into fpindles, pafs through the centres of the rollers *a*, and have collets and crofs keys to keep them on. In this manner, as the gudgeon and plate B turn round, the plate rolls upon the rollers *a*, *a*, keeping always in the true centre, by the end of the gudgeon *c* fitting the hole in the centre of the plate A A; but the weight is fupported by the rollers *a*, *a*, which, at the fame time that the upper plate rolls upon them, they roll upon the lower, and thus very confiderably diminifh the friction which any other kind of gudgeon would have in fuch a fituation.

Shafts.—In almoft all modern mills, the fhafts or fpindles for the conveyance of motion, and fupport of wheels, are made of iron, either wrought or caft. Square fhafts are the moft common, but fometimes octagon and round ones are ufed; and if they are very large, they are caft hollow, like pipes, and the gudgeons fixed in at the ends by wedges; but the pivots fhould always, if poffible, be formed of the fame piece of metal, as the flighteft poffible deviation from the ftraight line caufes them to ftrain, and work very irregularly in their bearings. In wooden fhafts this is impracticable, and it is one of the greateft objections to the ufe of them. The beft method of fixing gudgeons into wooden fhafts is fhewn in *fig*. 17. Here A is the gudgeon, made in caft iron, turned true; it has four leaves, *a*, *b*, *c*, *d*, forming a crofs, which is let into the end of the wooden fhaft R: the front edge of each leaf is confiderably thinner than the back, fo that a pair of ftrong iron hoops *r r* being driven tight on the end of the fhaft, clofes the wood round the crofs, and holds it faft, and the back of the leaves being wider than the front, it will not come out. As an additional fecurity, fcrews are fometimes put in: thefe are put through holes in the arms of the crofs, which are then made flat the other way, and do not go fo far into the wood. The fcrews go into the timber a confiderable diftance, where a mortife is cut into the wood, to meet the end of the bolt, and an iron nut is dropped in, to fcrew the bolt into, when it is turned round by a fcrew driver. By this contrivance a gudgeon may be fitted into a wooden fhaft very faft, but ftill it will never come into competition with iron fhafts, when the gudgeon is made all in one folid piece with the whole of the fhaft. A judicious mechanic will never make more than two bearings upon any one fhaft, if it can be avoided, becaufe if the three, by any means, as the warping of the frame work, or other caufe, get the fmalleft poffible quantity out of the ftraight line, they can never work well afterwards, but will always ftrain and wear the bearings with great friction In very extenfive mills, fuch as woollen and cotton mills, breweries, &c. when the buildings are of great length, it becomes neceffary to join feveral fhafts together in length, to reach from one end to the other of a mill. The manner of making the joinings is of fome confequence: it is neceffary that every fhaft fhould have a bearing at each end, and confequently that the connection of the ends of every one fhould be made by uniting the ends of the fhafts which project beyond their bearings. This can be done in various ways: one is by having the ends of each of the fhafts provided with circular heads (fee A B *fig*. 18.), which have teeth in one, and correfponding indentations in the other, to receive them, and thus one is made to turn the other about, at the fame time that if any flight fettlement of the building or other caufe depreffes one of the bearings, or raifes another, fo as to put the two fhafts out of the perfect ftraight line they ought always to preferve; thefe joints will admit the flight flexure, and ftill communicate the motion of one fhaft to the other.

As this accidental fettlement in large buildings is almoft unavoidable in fome degree, care fhould be taken to make fuch joints as will admit of a trifling bending. Sometimes the ends of the fhaft are made circular, and turned quite true in the lathe; then a metal tube or collar is fitted truly upon both to cover the joint, and connect them, a bolt being put through each end, which unites both fhafts with the collar, and thus by means of it caufes one to turn the other round. This method is fometimes ufed to fave the great expence of having a bearing at each end of every length of fhaft, one bearing to each length being then fufficient, the other end of the fhaft being fupported by this collar, connecting it with the end of the adjacent length juft where it projects beyond its bearing. But this is not a good method, as the fhafts are apt to bend and work with fo much friction in the bearings, if they get the leaft out of the ftraight line, becaufe thefe kind of joints will not admit any flexure of the fhaft, or if they do, they will only bend on one fide, whereas it is neceffary for the joint to bend fucceffively on all fides, when the bearings are not precifely in a ftraight line. *Plate* III. *fig*. 19. reprefents a coupling-box, ufed by Mr. Murray of Leeds, for connecting the lengths of a long line of fhaft which are to carry a heavy ftrain: it is fo made that it will communicate the motion in the manner of an univerfal joint, if they fhould be out of the line. Let A, B, be the two fhafts to be united; C, D, their necks or collars which lay in the bearings: the ends projecting beyond thefe have boxes E, F, fixed on them, either by a fquare with wedges, or by a round part with a fillet: one of thefe boxes, E, has a piece projecting from the infide of it on each fide, and extending into the other box, as is fhewn at *a a*, (No. 2.), which is an infide view: the other box, F, has two fimilar pieces projecting from it at *b b* into the other box E: within the boxes an iron crofs *c c d d* is fituated; it has fcrews fixed into the ends of the crofs, and by thefe the motion is communicated: thus, the pieces *a*, *a*, when the fhaft A and box E are turned round in the direction of the arrow (No. 2.) act againft the fcrews *c*, *c*, of the crofs, and turn

it about: at the ſame time the other two ſcrews *d, d*, at the other arms of the croſs preſs againſt the pieces *b, b*, which belong to the box F and ſhaft B, thus turning them round: the croſs is placed quite detached in the boxes, and thus acts as an univerſal joint, to communicate the motion of one to the other: the ſcrews *c c, d d*, at the ends of the croſs are only put in that the acting points may be made of ſteel, and made ſmooth to have but little friction in theſe parts. Another method of uniting ſhafts by Mr. Murray is ſhewn at *fig.* 20: it has the advantage of requiring only one bearing for every length of ſhaft, whereas the above method requires one for each end of every length. A, B, repreſent the two ſhafts; each has a pivot formed at the end: theſe pivots are fitted into a coupling piece C D E, which is bored out truly to fit them inſide, and the outſide turned true, with a neck D D, which is received and fitted into a bearing: the two ſhafts A, B, are connected with the coupling piece D, at C and E, by means of a croſs key *l m*, put through each ſhaft, and the ends of them received in notches made withinſide of the coupling piece at C and E, where it receives the ends of the ſhafts. It is to be obſerved that the ſhafts do not fit tight in theſe parts E and C, but only in the pivots *a, b*, within, by which means they have liberty of a little motion, and this without ſtraining the bearing in which D runs, becauſe it is only the ſhort coupling piece which is received therein; and conſequently, any trifling deviation from the ſtraight line will not ſtrain it, becauſe of the play allowed in the fittings.

The univerſal joint, called alſo Hooke's joint, from its inventor Dr. Hooke, is a method of uniting ſhafts, which permits them to be rather inclined to each other. This is ſhewn in *fig.* 21, where A, B, are the two ſhafts, with necks to be received in bearings: each ſhaft beyond this is formed into a fork, as C and D; and theſe are united by a croſs of iron E, or ſometimes a ring, in which four pins are inſerted, and paſs through holes in the ends of the forks. On one or other of theſe pins the joint will bend in any direction, on the ſame principle as a compaſs hangs in its gombals, and will communicate a rotative motion from one ſhaft to the other, when they are rather inclined; but this inclination ſhould be ſmall, or elſe the joint will not act well, or without great friction, and irregularity of motion. If an angle of more than 15 degrees from the ſtraight line is required, a pair of ſlightly bevilled wheels are beſt.

The regulation of the velocity of a mill is a matter of conſiderable importance, to preſerve an uniformity of motion, either when the force of the firſt mover is fluctuating, or when the reſiſtance or work of the mill varies in its degree: either or both of theſe cauſes will occaſion the mill to accelerate or diminiſh its velocity; and in many inſtances it will have a very injurious effect upon the operations of the mill. Thus, in a mill for ſpinning cotton, wool, flax, &c. driven by a water-wheel, are a multiplicity of movements, many of which are occaſionally diſengaged, in different parts of the mill, for various purpoſes. This tends to diminiſh the reſiſtance to the firſt mover, and the whole mill accelerates. Or, on the other hand, the head of water, which drives the wheel, may be liable to riſe and fall ſuddenly, from many cauſes, which great and rapid rivers are ſubject to, and cauſe ſimilar irregularities in the ſpeed of the wheel. For ſuch caſes, judicious mechanics have adopted contrivances, or regulators, which counteract all theſe cauſes of irregularity; and a large mill, ſo regulated, will move like a clock, with regard to its regularity of velocity. Theſe regulators are uſually termed *governors*, and are made on different principles. Thoſe moſt generally uſed are called flying-balls, operating by the centrifugal force of two heavy balls, which are connected and revolve with a vertical axis. *Fig.* 22. repreſents the ſimpleſt form of this ingenious apparatus: A A is the vertical axis, which is conſtantly revolving by the machinery; at *a a* two arms or pendulums, *a b, a b*, are jointed, and carry at their extremities a heavy metal ball each, as *b b*; from the pendulums two chains or iron rods, *d, d*, proceed, and ſuſpend a collar *e*, which ſlides freely up and down the axis, and has a groove formed all round it, in which the end of a forked lever, D, is received; and thus the riſing and falling of the collar, *e*, produces a correſponding motion of the end of the lever D; but the collar is always at liberty to turn round with the axis freely within the fork, at the extremity of the lever. The operation of the governor is this: when the vertical axis is put in motion, the centrifugal force of the balls, *b, b*, cauſes them to recede from the centre; and as this is done both together, they cauſe the collar, *e*, and the end of the lever to riſe up: the balls fly out to a certain height, and there they continue as long as the axis preſerves the ſame velocity; as it is the property of a pendulous ball, like *b*, to make a greater effort to return to the perpendicular, in proportion as it is removed farther from it, in conſequence of the ſuſpending rod being more inclined, and bearing leſs of its weight. The weight of the balls to return to the axis may be conſidered as a conſtantly increaſing quantity; while the quantity of the centrifugal force, cauſing them to recede from the axis, depends exactly upon the velocity given them. But this velocity increaſes as they open out, (independently of any increaſed velocity of the axis,) in conſequence of their deſcribing a larger circle. The combination of theſe oppoſitely acting forces cauſes the governor to be a moſt ſenſible and delicate regulator. Thus: ſuppoſe the balls hanging perpendicular, put the axis in motion with a certain velocity, the centrifugal force will cauſe the balls to fly out; and this increaſing their velocity, (by putting them farther from the centre, and cauſing them to revolve in a larger circle,) gives them a greater centrifugal force, which would carry them ſtill farther from the centre, but for the counteracting force, *viz.* the weight of the balls tending to return. This is, as before ſtated, an increaſing quantity, and conſequently theſe oppoſite forces come to a point where they balance each other; that is, the balls fly out till their weight to return balances the centrifugal force. But if the ſlighteſt alteration takes place in the velocity of the axis, the equilibrium is deſtroyed by the increaſe or diminution of the centrifugal force, and the balls alter their diſtance from the centre accordingly, and by elevating or depreſſing the end of the lever, operates upon ſome part of the mill to rectify the cauſe of the irregularity. In a ſteam-engine, the lever acts upon a vane or door ſituated in the paſſage of the ſteam from the boiler to the cylinder; and if the mill loſes in velocity, from an increaſe of reſiſtance, the balls fall together a little; and the conſequent fall of the lever opens the door or throttle valve a little wider, and gives a ſtronger ſupply of ſteam to reſtore the mill to its original velocity. On the other hand, if the mill accelerates, the balls open out and then cloſe the vane, ſo as to moderate the ſupply of ſteam. See a more full deſcription of this under STEAM-*Engine*.

A water-wheel is not ſo eaſily regulated by the governor, becauſe the ſhuttle of a large wheel requires a much greater force to raiſe or lower it, when the water is preſſing againſt it, than the lever, D, can at any time poſſeſs; it therefore becomes requiſite to introduce ſome additional machinery, which has ſufficient power to move the ſhuttle, and this is thrown, in or out of action, by the flying balls. The ſimpleſt contrivance, and that which we believe was the regulator firſt uſed for a water-wheel, was erected at a cotton mill at Belper, in Derbyſhire, belonging to Mr. Strutt.

A ſquare well, or large ciſtern, was ſituated cloſe by the water-wheel: it had a pipe leading from the mill-dam into it, to admit water; and another pipe from it to the mill-tail, to take the water away: both were cloſed at pleaſure by cocks or ſluices. Within the well was a large floating cheſt, very nearly filling up the ſpace: it of courſe roſe and fell with the water in the ciſtern, and had a communication by rack and wheel-work with the machinery for drawing the ſhuttle, ſo that the riſe and fall of the floating cheſt elevated and depreſſed the ſhuttle of the wheel. The lever of the governor was connected with the cocks in the two pipes, in ſuch a manner that when the mill was going at its intended velocity, both of the cocks were ſhut; but if the water-wheel went too ſlowly, the falling of the balls and deſcent of their lever, D, opened the cock in the pipe of ſupply, and, by letting water into the well, raiſed the float, and, with it, the ſhuttle, to let more water upon the wheel, till it acquired ſuch a velocity that the balls began to open out again, and thus ſhut the cock: on the other hand, if the mill went too faſt, the balls opened the pipe of exit from the well, and then the ſinking of the float cloſed the ſhuttle till the true velocity was reſtored.

Since this firſt application of the regulator to the water-wheel, the manner of its operation has been greatly varied; and as the ſame mechaniſm is applicable to any kind of mill-work, we ſhall give a ſlight ſketch of it. Suppoſe A, *fig.* 23, an axis, receiving its motion from the mill by wheel-work; it is provided with a pair of governors, *a b*, *a b*, conſtructed like thoſe before deſcribed; and at the lower part of the ſpindle is a bevilled wheel, R, turning two others, B and C, ſituated upon one ſpindle, D, which goes away, and communicates motion to the racks of the ſhuttle; the wheels, B and C, are neither of them fixed to the ſpindle D, but both ſlip round freely upon it, turning in contrary directions, as they receive motion from the oppoſite ſides of the wheel R. A locking clutch, *d*, is fitted upon the ſpindle between theſe two wheels, B, C, and can, by moving it one way or the other, be made to lock either one of the wheels to the ſpindle D, at the ſame time that it leaves the other diſengaged. The locking-box is moved by means of a lever, ſhewn in *fig.* 24; the arm *m*, having a fork to embrace a groove in the box; the lever is fixed on a vertical axis *n*, which has at the upper end two other levers, *o*, *p*: theſe lay one on each ſide of the vertical axis A, but at different heights, as is evident from the figure. The collar *e*, which is raiſed up when the balls fly out, is fitted upon a ſquare part of the ſpindle A, and is formed like a ſnail or camm, which will act upon either of the levers, *o* or *p*, according to the height at which it hangs upon its ſpindle. Now when the mill is going with its true velocity, this camm, *e*, is at ſuch a height that it is beneath one lever, *o*, and above the other, *p*, ſo as to interfere with neither; conſequently the locking-box, *d*, remains detached: but on any alteration in the velocity of the mill and the axis A, the balls open or ſhut, as before explained, and the camm, *e*, either riſes or falls, and then it preſſes againſt one of the levers, *o* or *p*, and by puſhing it away from the axis, it moves the lever *m*, and the locking-box *d*, up to one of the wheels, B or C, which it locks to the axis D, and turns it round in the direction of that wheel's motion, by which it either raiſes or depreſſes the water-wheel's ſhuttle, as is required. This apparatus may, it is plain, be applied to any other kind of mill-work.

Governors or flying-balls are very frequently uſed in the wind-mills employed for grinding flour: the variable force of this firſt mover renders ſome ſuch regulator neceſſary, to increaſe the reſiſtance, by allowing a greater feed of corn, when the mill moves too quickly, and thus in ſome degree counteracting the irregularity. If the mill moves too ſlowly, the balls tend to diminiſh the feed, and at the ſame time they raiſe the upper ſtone, to ſet them at a greater diſtance aſunder, that they may require leſs power to drive them, and conſequently ſuffer the mill, as nearly as it can, to retain its full velocity, though the motive force is greatly diminiſhed. This application of the governor was, we believe, firſt made by the ingenious captain Hooper of Margate, who invented the horizontal wind-mill. (See Wind-*Mill*.) It is a very great advantage, and no wind-mill ſhould be without them. Many wind-mills are provided with flying-balls, which, by very ingenious mechaniſm, clothe and unclothe the ſails juſt in proportion to the ſtrength of the wind.

In many mills it is of conſequence to be able to detect ſmall variations in the velocity, and to aſcertain the quantity of them; for the governor only corrects the irregularities, without ſhewing any ſcale of them. In caſes where this is required, it may be done by a very ingenious inſtrument, invented by Mr. Bryan Donkin of Fort-Place, Bermondſey. He received a gold medal from the Society of Arts, Manufactures, and Commerce, in 1810, for this inſtrument, which he calls a tachometer.

A front view of this inſtrument is repreſented in *fig.* 25, and a ſide view in *fig.* 26, of *Plate* II. X Y Z, *fig.* 25, is the vertical ſection of a wooden cup, made of box, which is drawn in elevation at X, *fig.* 26. The whiter parts of the ſection, in *fig.* 25, repreſent what is ſolid, and the dark parts what is hollow. This cup is filled with mercury up to the level L L, *fig.* 25. Into the mercury is immerſed the lower part of the upright glaſs tube A B, which is filled with coloured ſpirits of wine, and open at both ends, ſo that ſome of the mercury in the cup enters at the lower orifice, and, when every thing is at reſt, ſupports a long column of ſpirits, as repreſented in the figure. The bottom of the cup is faſtened by a ſcrew to a ſhort vertical ſpindle D, ſo that when the ſpindle is whirled round, the cup (whoſe figure is a ſolid of revolution) revolves at the ſame time round its axis, which coincides with that of the ſpindle.

In conſequence of this rotation, the mercury in the cup acquires a centrifugal force, by which its particles are thrown outwards, and that with greater intenſity, according as they are more diſtant from the axis, and according as the angular velocity is greater. Hence, on account of its fluidity, the mercury riſes higher and higher as it recedes from the axis, and conſequently ſinks in the middle of the cup; this elevation of the ſides and depreſſion in the middle increaſing always with the velocity of rotation. Now the mercury in the tube, though it does not revolve with the cup, cannot continue higher than the mercury immediately ſurrounding it, nor indeed ſo high, on account of the ſuperincumbent column of ſpirits. Thus the mercury in the tube will ſink, and conſequently the ſpirits alſo; but as that part of the tube which is within the cup is much wider than the part above it, the depreſſion of the ſpirits will be much greater than that of the mercury, being in the ſame proportion in which the ſquare of the larger diameter exceeds the ſquare of the ſmaller.

Let us now ſuppoſe, by means of a cord paſſing round a ſmall pulley F, and the wheel G or H, or in any other convenient way, the ſpindle, D, is connected with the machine whoſe velocity is to be aſcertained. In forming this connection, we muſt be careful to arrange matters, ſo that when the machine is moving at its quickeſt rate, the angular velocity of the cup ſhall not be ſo great as to depreſs the ſpirits below,

C, into the wider part of the tube. We are alſo, as in the figure, to have a ſcale of inches and tenths applied to A C, the upper and narrower part of the tube, the numeration being carried downwards from zero, which is to be placed at the point to which the column of ſpirit riſes when the cup is at reſt.

Then the inſtrument will be adjuſted, if we mark on the ſcale the point to which the column of ſpirits is depreſſed when the machine is moving with the velocity required. But, as in many caſes, and particularly in ſteam-engines, there is a continued oſcillation of velocity; in thoſe caſes we have to note the two points between which the column oſcillates during the moſt advantageous movement of the machine.

Here it is proper to obſerve, that the height of the column of ſpirits will vary with the temperature, when other circumſtances are the ſame. On this account the ſcale ought to be moveable, ſo that, by ſlipping it upwards or downwards, the zero may be placed at the point which the column reaches when the cup is at reſt, and thus the inſtrument may be adjuſted to the particular temperature with the utmoſt facility, and with ſufficient preciſion. The eſſential parts of the tachometer have now been mentioned, as well as the method of adjuſtment; but certain circumſtances remain to be ſtated.

The form of the cup is adapted to render a ſmaller quantity of mercury ſufficient than what muſt have been employed either with a cylindrical or hemiſpherical veſſel. In every caſe two precautions are neceſſary to be obſerved. Firſt, that when the cup is revolving with its greateſt velocity, the mercury in the middle ſhall not ſink ſo low as to allow any of the ſpirits in the tube to eſcape from the lower orifice; and that the mercury, when moſt diſtant from the axis, ſhould not be thrown out of the cup. Secondly, that when the cup is at reſt, the mercury ſhall riſe ſo high above the lower end of the tube that it may ſupport a column of ſpirits of the proper length.

Now, in order that the quantity of mercury, conſiſtent with theſe conditions, may be reduced to its minimum, it is neceſſary, firſt, that if M M (*fig.* 1.) is the level of the mercury at the axis when the cup is revolving with the greateſt velocity, the upper part M M X Y of the cup ſhould be of ſuch a form as to have the ſides covered only with a thin film of the fluid; and ſecondly, that, for the purpoſe of raiſing the ſmall quantity of mercury to the level L L, which may ſupport a proper height of ſpirits when the cup is at reſt, the cavity of the cup ſhould be, in a great meaſure, occupied by the block K K, having a cylindrical perforation in the middle of it for the immerſion of the tube, and leaving ſufficient room within and around it for the mercury to move freely, both along the ſides of the tube and of the veſſel.

The block, K K, is preſerved in its proper poſition in the cup or veſſel X Y Z, by means of three narrow projecting ſlips or ribs, placed at equal diſtances around it, and is kept from riſing or floating on the mercury by two or three ſmall iron or ſteel pins inſerted into the underſide of the cover, near the aperture through which the tube paſſes. It would be extremely difficult, nor is it by any means important, to give to the cup the exact form which would reduce the quantity of mercury to its minimum; but we ſhall have a ſufficient approximation, which may be executed with great preciſion, if the part of the cup above, M M, is made a parabolic conoid, the vertex of the generating parabola being at that point of the axis to which the mercury ſinks at its loweſt depreſſion, and the dimenſions of the parabola will be determined in the following manner. Let V G (*fig.* 27.) repreſent the axis of the cup, and V the point to which the mercury ſinks at its loweſt depreſſion: at any point, G, above V, draw G H perpendicular to V G; let n be the number of revolutions which the cup is to perform in 1″, at its quickeſt motion; let v be the number of inches which a body would deſcribe uniformly in 1″, with the velocity acquired in falling from reſt through a height = to G V, and make G H = $\frac{\quad}{314\, n}$. Then the parabola to be determined is that which has v for its vertex, V G for its axis, and G H for its ordinate: at G the cup has a lid to prevent the mercury from being thrown out of it, an event which would take place with a very moderate velocity of rotation, unleſs the ſides were raiſed to an inconvenient height; but the lid, by obſtructing the elevation of the ſides of the cup, will diminiſh the depreſſion in the middle, and, conſequently, the depreſſion of ſpirits in the tube: on this account, a cavity is formed in the block immediately above the level L L, where the mercury ſtands when the cup is at reſt, and thus a receptacle is given to the fluid which would otherwiſe diſturb the centrifugal force, and impair the ſenſibility of the inſtrument.

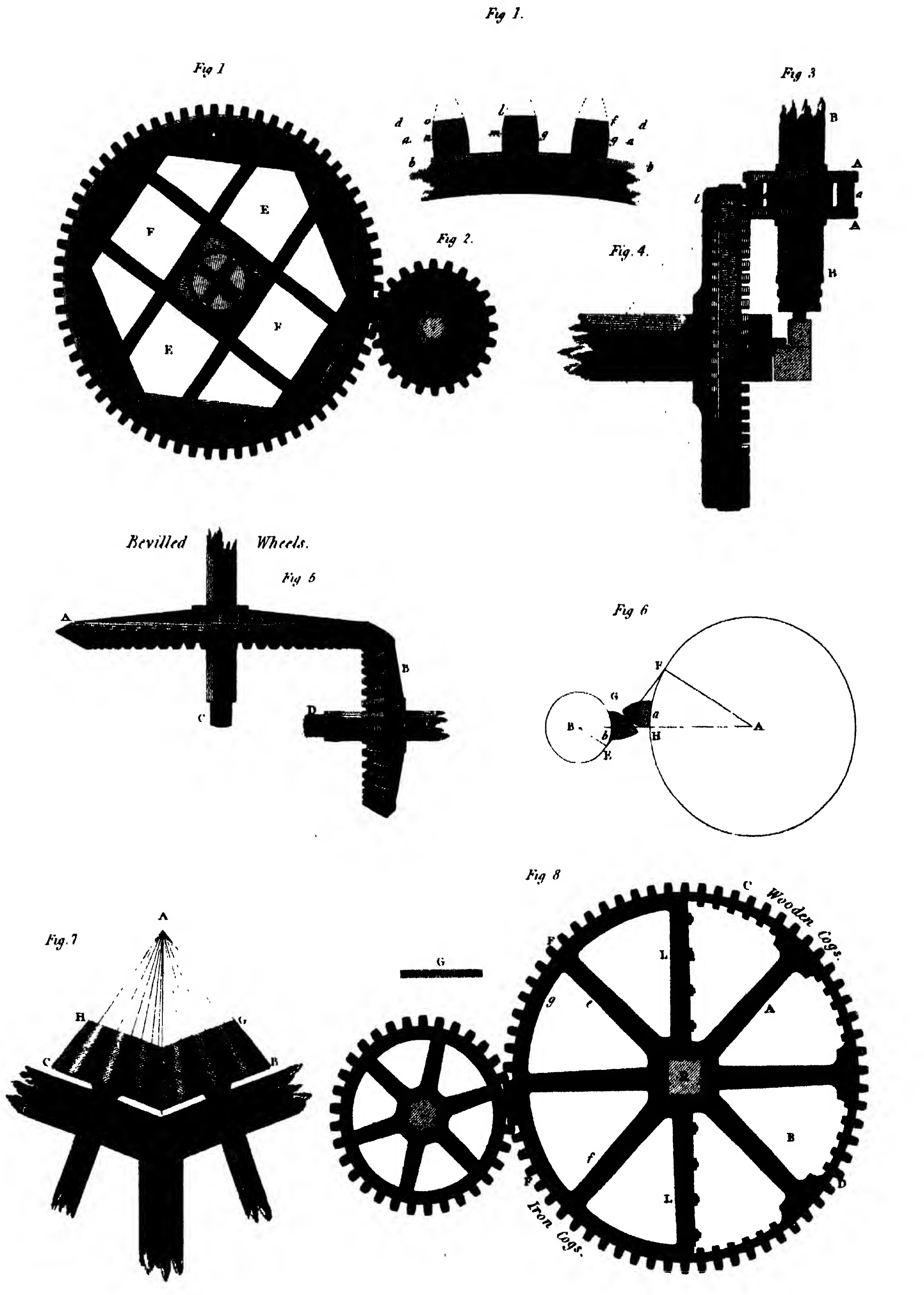
It will be obſerved, that the lower orifice of the tube is twined upwards. By theſe means, after the tube has been filled with ſpirits, by ſuction, and its upper orifice ſtopped with the finger, it may eaſily be conveyed to the cup, and immerſed in the quickſilver, without any danger of the ſpirits eſcaping, a circumſtance which otherwiſe it would be extremely difficult to prevent, ſince no part of the tube can be made capillary, conſiſtently with that free paſſage to the fluids which is eſſentially neceſſary to the operation of the inſtrument.

We have next to attend to the method of putting the tachometer in motion, whenever we wiſh to examine the velocity of the machine. The pulley F, which is conſtantly whirling during the motion of the machine, has no connection whatever with the cup, ſo long as the lever, Q R, is left to itſelf. But when this lever is raiſed, the hollow cone T, which is attached to the pulley, and whirls along with it, is alſo raiſed, and, embracing a ſolid cone on the ſpindle of the cup, communicates the rotation by friction. When our obſervation is made, we have only to allow the lever to drop by its own weight, and the two cones will be diſengaged, and the cup remain at reſt.

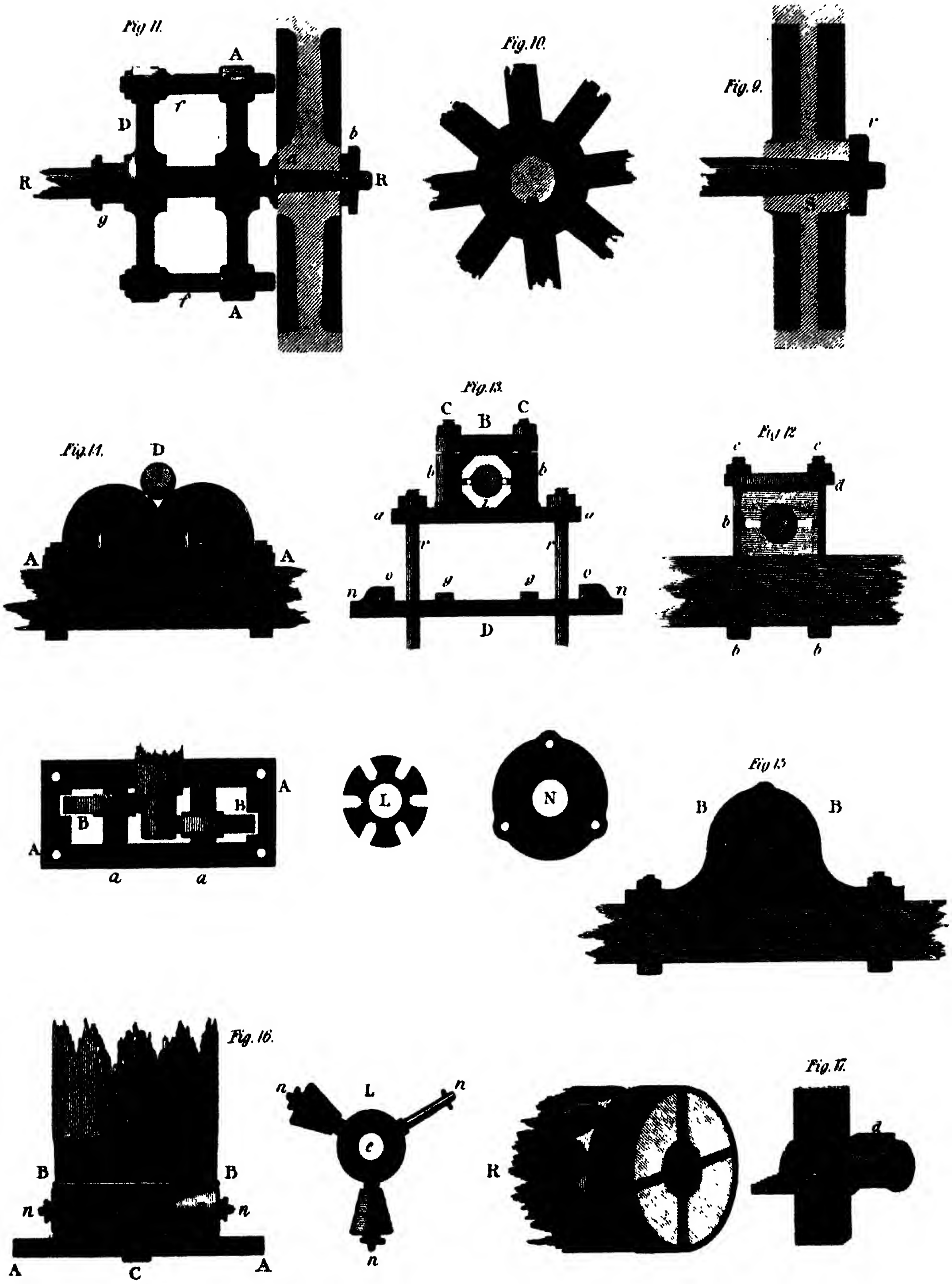
The lever, Q R, is connected, by a vertical rod, to another lever S, having at the extremity, S, a valve, which, when the lever, Q R, is raiſed, and the tachometer is in motion, is lifted up from the top of the tube, ſo as to admit the external air upon the depreſſion of the ſpirits. On the other hand, when the lever, Q R, falls, and the cup is at reſt, the valve at S cloſes the tube, and prevents the ſpirits from being waſted by evaporation.

It is, laſtly, to be remarked, that both the ſenſibility and the range of the inſtrument may be infinitely increaſed; for, on the one hand, by enlarging the proportion between the diameters of the wide and narrow parts of the tube, we enlarge, in a much higher proportion, the extent of ſcale correſponding to any given variation of velocity; and, on the other hand, by deepening the cup, ſo as to admit, when it is at reſt, a greater height of mercury above the lower end of the tube, we lengthen the column of ſpirits which the mercury can ſupport, and, conſequently, enlarge the velocity which, with any given ſenſibility of the inſtrument, is requiſite to depreſs the ſpirits to the bottom of the ſcale. Hence the tachometer is capable of being employed in very delicate philoſophical experiments, more eſpecially as a ſcale might be applied to it indicating equal increments of

velocity. But, in the present account, it is merely intended to ſtate how it may be adapted to detect, in machinery, every deviation from the moſt advantageous movement.



J. Farey Jun. del. Published as the Act directs, 1813, by Longman, Hurst, Rees, Orme & Brown Paternoster Row London Engr.



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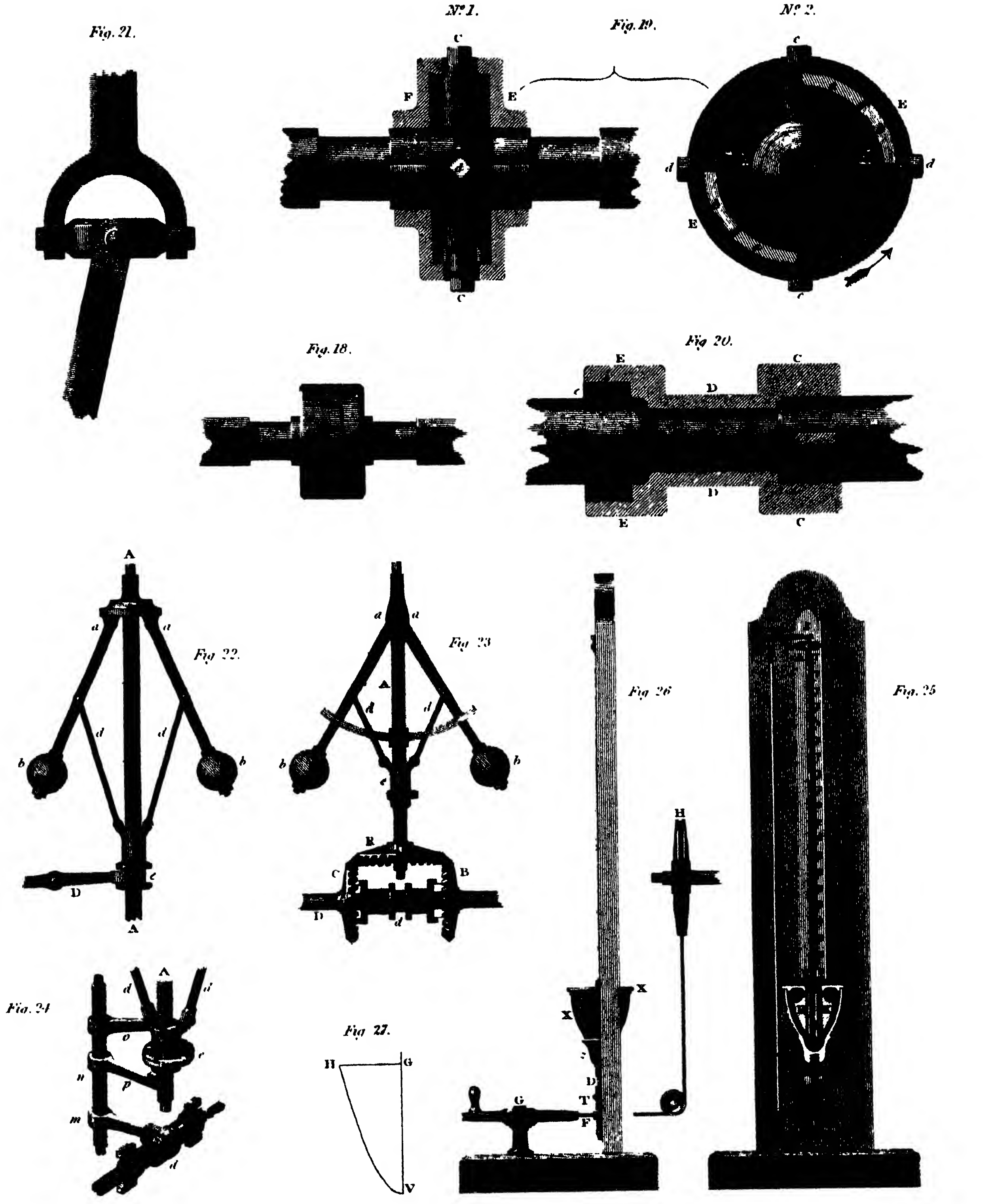

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Milling

MILLING, in the *Manufactories*, an operation called also *fulling*.

MILLING, or *throwing of silk*, is the last preparation of silk before dyeing; serving to twist it, more or less, according to the work for which it is intended.

To prepare the silk for milling, they first put it in boiling water, inclosed between two linen cloths. The mill is a square machine, composed of several pieces of wood, mortised in each other, so as to form a kind of large cage, in the centre of which are two wheels placed parallel over each other, whose axis bears on two posts. When the machine is simple, a single man turns these wheels by means of a little cog, in which they catch, and a large handle.

The wheels, put in motion by the handle, communicate their motion to eight windles, or reels, or even more, according to the largeness of the machine; on the flights or arms of which the silk is wound from off two rows of bobbins placed on each side of the machine; each row at the height of one of the two wheels in the centre. These bobbins have their motion by means of leathern thongs, which bear on little cylinders of wood that support them, and turn at length on the two wheels at the centre; so that the silk on each bobbin twists as it winds, and forms its separate skain.

The smallest wheel moves two hundred of these bobbins, over which a single person is sufficient to inspect, to put new bobbins or spoils in lieu of those discharged of their silk, and to knot the ends when they break. See WINDING *of Silk*.

Mine

Mine. This word is applied generally to all works carried on under ground, but seems principally to belong to such as have for their object the discovery and production of the metallic ores.

The construction of the works in various mines differs according to circumstances, such as the form of the hills in which they are situated, or the position of the ores, whether found in veins or beds. Some mines are formed by a level or drift entering the foot of a mountain, and extending to the deposits of metal within it, which may be taken away and carried out through this opening; and in this case *shafts* are only required for the purposes of ventilation.

This seems to be the simplest state of mining, and is, as well as such mines as have been formed by following ore from the surface to such depths as water would permit, to be ranked among the earlier efforts of this kind.

The more extended operations of mining are to be found where regular metallic veins, situated in primitive rocks, are worked to great depths below the level of the sea, where perpendicular *shafts*, drained of the constantly accumulating water by engines, form the means of communication from the surface to *levels* driven upon the *lode* or vein, at various and successive depths, so as to open all parts of it for the discovery of its contents.

A mine thus constructed, of any considerable extent, is one of the most extraordinary instances of human enterprize, patience, and ingenuity; especially if it be considered that its formation depends upon the application of two of the most wonderful discoveries on record, the expansive forces of gunpowder and steam.

Mines in Cornwall and Devon are generally worked by a company of proprietors, called adventurers, who agree with the owner of the land, or lord of the soil, as he is usually denominated, to work the mine for a certain term of years, paying him, by way of rent, a proportion of the ores raised, or an equivalent in money. The grant thus made to the adventurers is called a *set*, and the lord's rent, if paid in ore, is called the *dish* (probably from the ancient practice of measuring it by a vessel of that sort), and when settled for in money, has the term *dues* applied to it.

The adventurers divide their undertaking into shares of different magnitude, but usually forming in the whole some even and easily divisible number. The smallest share usually held by one adventurer is one sixty-fourth part, though in some large mines this share is divided, and a person may then have only a one hundred and twenty-eighth part of the whole, while others may hold eighths, others sixteenths or thirty-seconds, and some larger proportions, but the whole added together make up sixty-four shares. Any part of the concern held by one person is generally called a *dole*, and distinguished as to its relation to the whole by adjoining to this word the denomination of its value, as an eighth dole, a sixteenth dole, &c.

Mines in Cornwall and Devon are usually named as soon as they are undertaken, and this practice seems to have been of considerable antiquity, as the word *wheal*, or *huel*, usually even now prefixed to these appellations, is derived from the ancient Cornish language, and signifies a work or mine. The other parts of the names of mines often relate to the situation, or have been given in compliment to some person connected with them, or adopted according to the fancy of the adventurers. Thus Wheal Rose is probably derived from the Cornish word *ros*, a valley, and means therefore the mine in the valley; Wheal Godolphin has the name of a family; and among the arbitrary appellations which are the most numerous, may be instanced Wheal Unity, Wheal Virgin, Wheal Jewel, &c.

The *bounds*, or limits of the set of a mine, are usually marked out upon the surface and include the space of ground in which any company of adventurers have contracted for the right working. Bounds for working tin are recognized by the stannary laws of Devon and Cornwall, as a property in themselves distinct from the possession of the soil, and were probably originally granted to encourage the search for this metal by the laws of the duchy, that the revenue of the chief lord might not suffer by the unwillingness of the possessor of the soil to have its surface disturbed. Tin bounds that have been legally renewed, or possession retained, are even now in their original state in this respect; but copper mines, and also many tin mines, are now generally held of the possessor of the fee.

Mines are generally conducted in Cornwall and Devon by a manager appointed by the adventurers, who hold meetings at the counting-house to revise and pass the accounts, and to debate and determine on all subjects relative to the prosecution of the works submitted to them.

Under the principal agent others are appointed, who are practical miners, and who superintend the various operations and settle the terms of the contracts with the workmen, which are made by a kind of public auction. These agents are called *captains*, and the number employed in a mine is in proportion to its extent and importance. Some attend principally to the works below, and are therefore called *underground captains*; others take charge of the operations on the surface, and are therefore distinguished by the appellation of *grass captains*. It would be injustice to this useful and respectable body of men to pass them over without noticing the intelligence, activity, and skill by which the agents of the mines in the districts alluded to are distinguished.

The establishment of a mine further includes occasionally an engineer, a head carpenter and smith, who have each their workmen under their care; a *pitman*, who directs the fixing and repair of the pump-work; a *timberman* or *binder*, who superintends the construction of the woodwork under ground, for securing the shafts, ladders, levels, and so on: and besides these operative men, there are usually clerks to keep the accounts, and persons to receive and deliver to the workmen the materials used in their operations.

The miners working under ground are divided into two classes, according to the mode by which they are paid. Those of the first class are called *tributers*, who work on the productive parts of the mine, and receive a proportion of the ore which they procure and make merchantable, for their labour. This mode of payment, by its occasionally leading to unusual profit, stimulates to great exertion in the discovery of fresh deposits of ore, and is therefore conducive to the interests of the employer as well as the workman. To the reward thus held out to skill and intelligence, may probably be attributed the prevalence of these qualities, which may be observed more particularly in this class of Cornish miners. The other workmen employed under ground are denominated *tutwork-men*, who agree for sinking shafts, driving levels, and so on, at a certain price *per* fathom. These prices are exceedingly various, as the rock to be penetrated differs in de-

grees of hardneſs, or the nature of the work expoſes the men to more or leſs danger or inconvenience from water or bad air.

The people employed on the ſurface in dreſſing the ores, generally perform their labour by taſk-work, the amounts being charged to the account of the tributers, whoſe ore is undergoing this proceſs.

The copper ores, when ready for ſale, are ſampled by agents of the ſmelting companies, who viſit the mines for that purpoſe, and are ſold on a fixed day by a public ſale, called a *ticketing*, and afterwards weighed and carried to a port and ſhipped to Wales, where the copper ſmelting houſes in general are. Tin ores are ſmelted in Cornwall, and are ſold by the miner to the owners of the ſmelting houſes by private contract, valuing them by an aſſay made by the buyer. In this reſpect the value of tin ores is determined by a mode much more uncertain and irregular than that employed for copper, the aſſay of which is conducted with extreme care, and wonderful accuracy.

The extent of the returns and coſts of the mines in Cornwall and Devon, both collectively and ſeparately, may be ſeen by referring to the hiſtory of mining in this diſtrict, where the tables of the ſtate of theſe concerns exhibit a very intereſting picture of the great increaſe of theſe extenſive undertakings. See MINING, *Hiſtory of*.

The king by his prerogative hath all mines of gold and ſilver to make money; and therefore thoſe mines, which are properly royal, and to which the king is entitled when found, are only thoſe of ſilver and gold. (2 Inſt. 577.) By the old common law, if gold or ſilver be found in mines of baſe metal, according to the opinion of ſome, the whole was a royal mine, and belonged to the king; though others ſay that this was only the caſe, when the quantity of gold or ſilver was of greater value than the quantity of baſe metal. (Plowd. 336.) But by ſtatute no mines of copper, tin, iron, or lead, ſhall be adjudged royal mines, though gold or ſilver be extracted. (1 W. and M. c. 30.) And perſons having mines of copper, tin, lead, &c. ſhall enjoy the ſame, although claimed to be royal mines; but the king, or perſons claiming royal mines under his authority, may have the ore (except tin-ore in Devon and Cornwall) paying to the owners of the mines, within thirty days after it ſhall be raiſed, and before removed, 16*l.* *per* ton for copper-ore waſhed, and made merchantable; for lead-ore 9*l.* *per* ton; tin or iron, 40*s.* &c. (Stat. 5 W. & M. c. 6.) If any perſon maliciouſly ſet on fire any mine, or pit of coal, he ſhall be guilty of felony, without benefit of clergy, by ſtat. 10 Geo. II. c. 32. If any perſon ſhall wilfully or maliciouſly ſet fire to, burn, demoliſh, pull down, or otherwiſe deſtroy or damage any fire-engine, or other engine erected for draining water from coal mines, or for drawing coals out of the ſame; or for draining water from any mine of lead, tin, copper, or other mineral, or any bridge, waggon-way, or trunk erected for conveying coals from any coal mine, or ſtaith for depoſiting the ſame; or any bridge, or waggon-way erected for conveying lead, tin, copper, or any other mineral, from ſuch mine, or cauſe the ſame to be done, he ſhall be guilty of felony, and tranſported for ſeven years. (9 Geo. III. c. 29.) Provided that no perſon be proſecuted under this act beyond 18 months after the offence committed. By 39 & 40 Geo. III. c. 77, deſtroying or damaging mines or roads leading to or from the ſame, &c. incurs the guilt of miſdemeanor, and any one perſon ſo offending may, on conviction, be impriſoned for any time not exceeding ſix months. Colliers and miners working in a manner contrary to their agreement, or not fulfilling their contracts, ſhall, on conviction, forfeit not exceeding 40*s.* and on non-payment be impriſoned for a time not exceeding ſix months, or until the penalty and coſts ſhall be paid. Stealing ore out of mines is no larceny, except only thoſe of black-lead, the ſtealing ore out of which is felony, puniſhable with impriſonment and whipping, or tranſportation not exceeding ſeven years, and eſcaping from ſuch impriſonment, or returning from tranſportation is felony, without benefit of clergy. by 25 Geo II c. 10.

MINE-*adventurers*, *Company of*, had its firſt riſe about the year 1690, when certain mines of lead and copper were found in South Wales, which were divided by the proprietors into twenty-four ſhares; and in 1693 ſub-divided into four thouſand and eight ſhares, for the term of twenty-two years and a half; to which term five years more were added in 1698, and the affairs of the company regulated by a new conſtitution. In 1704, queen Anne granted a charter of incorporation to this company; in conſequence of which ſeveral new ſhares were added, ſo that the whole number amounted to ſix thouſand and twelve. However, the intereſts of this corporation were ſo ill managed, that the proprietors and creditors petitioned parliament in 1710, and a committee of the houſe of commons was appointed to enquire into its ſtate. The reſult of the enquiry was a cenſure on the principal managers; and though, in 1711, a law was paſſed for the better regulation of the company, and the relief of the creditors and proprietors, nothing could preſerve it from ſinking.

Mining

MINING, *History of.* To trace this subject up to its earliest stages, and to exhibit the various combinations of human ingenuity which it has in successive periods produced, though an inquiry which might afford matter for curious speculation, would be one which, if we were to take into the view the progress of mining in all the different countries where metals have been found, would extend the subject to a length hardly admissible in any work not wholly devoted to this object.

From the simplest operations, mankind have been gradually led, by following the pursuit of the metals, to efforts the most complex and astonishing. At first it may be assumed, not only from the probability of the thing, but from evidence which even this country affords, in the remains of ancient works of this kind, that metals were procured from detached fragments of the ores, such as had been separated by various causes from the upper parts of the veins in which they were originally deposited: and in this manner is gold yet procured, by washing the sands of certain rivers; and tin even now sought after, under beds of gravel, in the vallies of Cornwall and Devon.

The pursuit of scattered pieces of ore naturally would conduct the persons, who were thus employed, to the beds from which they had been detached; and in turning over the soil to procure the loose fragments, the backs of the veins would be laid open and discovered. This is a process which is even now daily going on in mining districts, only with a different object: for having found an accidental stone of ore, the miner does not now dig over the earth on the surface, for the sake of these casual deposits; but reasoning from their appearance that a vein is near at hand, goes at once to work in order to find it.

If we allow that this account of the origin of mining be true, it ought to follow that those metals were most anciently worked, whose ores are most attractive in their appearance, most easily reduced into a metallic state, or such as are most usually found near the surface of the earth. As far as the English mines afford us the means of judging, all this may be asserted to be true. The tin of Cornwall was undoubtedly the first metal sought after in Britain, and probably the first article of commerce with other nations; and the ores of tin, from their great weight, indicate their metallic contents, and yield them to the simplest treatment with fire, and are still found at inconsiderable depths. It may also be observed, that the traces of the most ancient tin works exhibit no symptoms of their having been pursued, but in situations where the soil, with which it was mixed, could be easily and expeditiously removed; or where it

could be washed away by streams of water, conducted over it for the purpose, and which, by carrying off the lighter parts of the soil, laid bare the ores, which are kept from moving by their superior specific gravity.

This latter was an ingenious improvement upon the first ruder efforts, and is still the mode employed in many of the tin stream works; while there are numerous traces of these attempts accompanied with circumstances, which prove them of very considerable antiquity.

Lead is another metal, which not only is often found near the surface, but the ores exhibit to the eye the appearance of metal, and in general yield their contents to the heat of a moderate fire. This metal, therefore, was probably an object of pursuit in the early ages of mining.

Copper, on the other hand, is seldom found without penetrating the earth to considerable depths; and the proportion of metal in most of the ores is so small, that a certain progress in the arts of mining and smelting must be presumed to have been made, before it could have become an object of research. We believe this to have been the fact in most countries, as well as in this, where copper was certainly discovered by working mines in pursuit of tin or lead.

From the processes for finding and separating metallic ores from alluvial matter in which they were casually mixed, the next step was to procure them by digging out the veins themselves, and following them into the solid rocks in which they are formed. At first this could only have been done, where, by the elevation of the mountains, it was possible to work high enough for the waters to discharge themselves by conduits or adits from the works; and where the rock was not so hard but to yield to tools rudely formed, or perhaps to the agency of fire, which would, however, produce but a limited effect in most cases.

It was not until machines were applied to pump the waters, that the metals could be followed to any considerable depth, and not until gunpowder had furnished the means of splitting the hardest rock, that man was enabled to penetrate strata of every description that opposed his progress.

These inventions, therefore, form most important epochs in the history of mining; for, since mankind have called in the assistance of such powerful agents, neither the influx of constantly flowing water, nor the barriers which the most indurated rock can present, are obstacles in the way of the miner, where rich and productive veins of ore tempt the pursuit.

The first important era was the period in which the application of gunpowder to the purposes of mining took place, which happened in Hungary, or Germany, about the year 1620, and was first introduced into England at the copper-mine at Ecton, in Staffordshire, about the year 1670, by some German miners brought over by prince Rupert. It was in use in Somersetshire about 1684, and it was not until after this period, probably, that the Cornish miners became acquainted with this powerful assistant to their operations.

Its importance may be judged of by the amount of the present consumption in the mines of Cornwall alone, which has been calculated at an annual value of about forty thousand pounds sterling.

There are many mines which could not possibly have been worked without the aid of gunpowder, and, until it was used, subterranean operations must have been difficult and very uncertain. The hammer and wedges were probably the first instruments employed for splitting rocks, and the *pick* followed, which is used both as a hammer and a wedge. The change of form in these instruments observed in those which have been found in old works, as well as the materials of which they are sometimes made, offer evidence of considerable antiquity.

Many tools of oak have been occasionally met with, which tradition among the Cornish tinners make to have belonged to the Saxons or Danes, but it is probable that they were employed before the time of their having a footing in the country, and most likely when iron was little known here.

Wedges of dry wood were made use of by driving them into clefts of the rock, and then wetting them, so as to cause them to swell, and thus by repeated similar insertions to force the ground asunder.

Agricola describes the application of fire to the splitting of rocks, but there is no tradition of its having been applied to this purpose in England.

The means employed for raising or throwing up the ores and waste stuff to the surface, were at first as rude as the other operations of mining. The *windlass and bucket* may be reckoned an improvement which took place in a later stage of mining, as simple a one as it certainly is, and now in a great measure superseded by more effective machinery. It was, however, at the time an important addition to the apparatus of mines, as water as well as ore could thus be raised to moderate heights; and by the employment of much manual labour with a number of such machines, even considerable excavations were kept free from water, and had their produce lifted to the surface.

The windlass, probably, like most of the early improvements in mining, had its origin in Germany, and before it was introduced here from that country, the mode adopted for throwing up the stuff dug in the bottom of the deeper pits, was by making successive steps, or stages, which were called in Cornwall *shammels*; upon each of which men were placed, who raised the excavated matter from one to the other, until it thus reached the highest point.

In South America the windlass is even yet hardly known, and the ores are either carried up by the Indians employed in the mines, or, where the situation admits of sloping roads being made to the bottoms, are conveyed to the surface on the backs of mules.

When mines were worked deep, the labour of raising the water which was constantly collecting, became too great for mere manual exertion, and hydraulic machines were invented or employed for the purpose. Pumps were adapted to the shafts, and their constant action secured by giving motion to their pistons by wheels turned by descending streams of water. Where supplies of this agent can be obtained, and the form of the country admits of its application with considerable falls, nothing better can be desired, as it is a more regular power than steam, and infinitely less expensive; it has, therefore, continued in use to the present day, where circumstances admit of its being applied.

The German miners seem in all probability to have had the merit of these inventions, as they appear to have been completely in use among them when Agricola wrote, who fully describes their contruction and application.

But though Germany may fairly claim the invention of these engines for this purpose, yet nothing more has been done there; but, on the contrary, they are said to remain now there in nearly the same state as at their original introduction. The English miner has improved the pump-work and the water-engines to their present high state of perfection in this country.

It is in some degree owing to necessity that this has been the case, as there are single mines in England which require that as much water be discharged from them, as the pumps of a whole province of German mines could effect. There

is, indeed, no need to prove the capacity of English artists for mechanical improvement.

Hydraulic machines, however, as they require falls of water to put them into motion, can only be erected where the circumstances of a country afford the means of working them; and if nothing further had been done, many of our most valuable mines in Cornwall, not to mention our collieries and lead mines, would have remained unexplored and unproductive. The invention of the *steam-engine* gave to the miner a power capable of universal application, and of an effect that added, as it were, new regions of subterranean country to his controul. Depths hitherto unattainable are now placed at his command, and no limit can be assigned to his exertion, but that of the expence compared with the value of the produce.

The history of the steam-engine will be a subject for another place; but we may here observe, that the invention very early excited the attention of the mine owners of Cornwall, who successively adopted and encouraged the improvements of Savary, Newcomen, and Watt.

In this district some of the earliest efforts of these ingenious men were seconded and rewarded, and in return the mines have gained such assistance as could not have been formerly anticipated or imagined.

The general history of mining in England has never been very accurately traced; the districts famous for their mineral products have no communication with each other on this account, and have no common mineral laws or customs.

In other countries mining has been fostered and protected by the state, immunities have been granted, the workmen have been surrounded by particular privileges, and their operations encouraged by grants of timber from royal forests, or the free use of lands and waters. Thus peculiar systems of laws have often arisen where the mines were important as a source of revenue to the state. Something of this sort is indeed to be traced in the stannary laws of Cornwall; these laws, however, are not operative in the other mining districts England, but are confined to the counties of Devon and Cornwall, which are both included in the royal duchy which bears the name of the latter. Here the stannary laws still existing, now afford the miner but scanty assistance, though they effectually provide for the secure payment of the mineral revenue to the duke of Cornwall. To this object, and to the adjusting disputes touching the affairs of tin mines, the present administration of these laws may be said to be directed. The protection to the person of the tinner, as to military service and processes from other courts, has been gradually removed, and the rights of embounding lands for his pursuits, and of obtaining water-courses for his engines, have been questioned, and, in some cases, rendered doubtful. It cannot, perhaps, be contended that these laws could now be exercised in their former construction in the present state of property; but a revision, accommodating them to the fair wants of the miner, without prejudice to the land owner, would be attended with much benefit to the mining interest.

The copper-mines, being altogether of later date than those of tin, partake of none of the advantages which the stannary laws afford, and are therefore governed more by custom than any thing else; an extension of the privileges of the tin mines to these, and a legal provision for the peculiar arrangements which such undertakings require, would remove many serious obstacles to their prosecution.

Mining in England had a very early origin, compared with the progress of other arts in the country; it was in all probability the first source of trade to these islands, and the tin of Britain was known in distant parts of the world at a very remote period. It is generally believed that the Phœnicians were the nation principally engaged in trading to Britain for this metal. Tin works were carried on before iron was in use in England, as may be presumed from the tools of oak which have been found in ancient mines. Cicero affirmed that no silver was to be found in Britain, and though it has since been proved that he was wrong in that respect, yet the notice taken of the subject serves to shew that the metals of the country were the principal temptation to the Roman conquerors.

The Saxons neglected the pursuit of the metals, but the Normans appear to have worked for them to advantage, and from this time, until the reign of king John, the mines were mostly in the hands of Jews, when they are said not to have been successful, but in the reign ensuing they were worked by the same people with more effect. Edward I. caused the Jews to be banished, and the mines were, in consequence, neglected, until Edmund, the elder son of that king, and earl of Cornwall, willing to restore what had produced so large a proportion of the revenues of his domain, made grants important to the miner, which were confirmed by the king, by a charter in the 33d year of his reign; which states that

"For the advancement of the stannaries, he frees the tinners from all pleas of the natives touching the court, and from answering before any justices, &c. save only the keeper of the stannaries; (pleas of land, life, and member excepted) neither are they to be kept from work but by the said keeper." And it further "indemnifies them from tolls, &c., gives them libertie to dig tin and turf any where in the said countie, and to turn water-courses for their works at pleasure; with many other privileges."

It is from this time that the enactment of laws for the government of the stannaries may principally be dated.

Power to search for other metals besides tin was granted to individuals immediately from the crown, and we find that various persons held the right of searching for mines in the reigns of Edward III. Richard II. Hen. IV. and Hen. VI. In some of these grants, gold, silver, and copper are mentioned as well as lead.

The privileges of the tinners were not interfered with by any question relating to these metals, nor, on the other hand, did the jurisdiction of the stannaries extend to affairs connected with them.

Thus we find an appeal to the exchequer in the reign of Henry VI. relative to lead mines. *From the records, Easter term, anno 36. Regni. Devon Memorand.* "That John Bottwright, governor of the mines of Bury Ferrers in Devon, complains to this court that Robert Glover, at the command of Roger Champernown, took away 144 bouls of glance oar, valued at 15*l.* 6*s.* 8*d.* and made profit of the same without any thing allowed to the king, to the king's damage of 100*l.* and thereupon desireth the advice of the court."

The mines continued to be protected by the crown, and particularly by Henry VII., until Edward VI., when they were neglected; and fell into complete decay during the disastrous government of Mary.

When Elizabeth succeeded to the crown, the mines of the kingdom partook of the attention which this enterprising queen bestowed on every object from which an increase to the resources, or an addition to the strength of her government, might be derived.

The failure of the mines had diminished the number, and annihilated the skill, of the English miners; the queen therefore invited over Germans, and made extensive grants in different parts of England to Houghsetter and Thurland, and likewise others to William Humphreys and Christopher Shutz. She also established, in 1568, a corporation, which still exists, called "The Society for the Mines Royal," which had certain grants and privileges in several counties, and of

which William, earl of Pembroke, was the firſt governor. It does not appear that this ſociety, which was originally a mining company, though now engaged in ſmelting ores only, produced any important effect upon the diſcovery of metals in England; the tin mines of Cornwall were not worked by them, but remained in the hands of private adventurers, under the juriſdiction of the ſtannaries, and increaſed in produce and value in proportion to the demand for this metal. The whole amount of tin annually raiſed in Devon and Cornwall, in the following reigns of James I. and Charles, was from fourteen hundred to ſixteen hundred tons. It is probable that the civil wars which ſucceeded injured the workings of the mines, as in the reign of Charles II. it appears from a note of Mr. Scawen, of Molinek, who was vice warden of the ſtannaries, and quoted by Dr. Pryce, that the tin revenues were very ſmall.

In the reigns of Anne and George I. the produce of tin had again become conſiderable, and amounted, one year with another, to ſomething more than ſixteen hundred tons; ſo that in the ſpace of 110 years its mean proportion was equal to fifteen hundred tons *per annum*.

Since the foregoing time a gradual increaſe took place in the enſuing thirty years; for in the year 1742 a propoſal was made by the Mines Royal Company in London to raiſe one hundred and forty thouſand pounds to encourage the tin trade by farming that commodity for ſeven years at a certain price. A committee of Corniſh gentlemen were appointed to conſider of the propoſal; and they reported, "That the quantity of tin raiſed yearly in Cornwall, at an average for many years laſt paſt, hath been about two thouſand one hundred tons;" and reſolved, "That three pounds nine ſhillings for grain tin, and three pounds five ſhillings *per* hundred weight for common tin, are the loweſt prices for which ſuch tin will be ſold to the contractors, excluſive of all coinage duties and fees."

The produce of the tin mines was much more conſiderable afterwards, and from 1760 to 1780 it was reckoned at about two thouſand eight hundred tons a-year, which was worth the annual ſum of about 180,000*l*.

Copper began to be worked in Cornwall in the beginning of the 18th century, and the amount had attained at the period juſt quoted to about the ſame annual ſum of 180,000*l*. making the mineral returns of this diſtrict at this period, *viz*. about 1780, to be of the yearly value of 360,000*l*.

The tin mines have not been ſo important to the Corniſh miners ſince the diſcovery of copper as they were before, the produce of the latter having increaſed moſt rapidly, while the former have not made any proportional progreſs. As the ſubject is very intereſting in eſtimating the power of this country to ſupply raw materials for its numerous manufactures, we ſhall give ſtatements of the produce and other particulars of the tin and copper mines of Cornwall and Devon, from the early part of the laſt century to the preſent time.

We ſhall firſt ſtate the produce of the tin mines, and afterwards give a more detailed account of the effect of the diſcovery of copper on the mining intereſt as well as the trade of the country.

The chief part of the tin in the following ſtatement was produced from the mines of Cornwall alone, as although Devon had anciently yielded a large proportion of tin, yet before this period the mines, or rather the ſtream works of the latter county had become exhauſted, and were incapable of producing any notable proportion of ore.

Account of the Quantity and Value of Tin raiſed in Cornwall and Devon, from 1700 to 1800.

Dates.	Number of Blocks 6½ to a Ton.	Number of Tons.	Price *per* Ton. £. s. d.	Periods.	Annual Quantity in Tons.	Annual Value. £. s. d.
1700 to 1720	208,000	32,000		20 years	1600	
1720 to 1740	273,000	42,000	66 0 0	20 years	2100	138,600 0 0
1740 to 1750	162,500	25,000	65 0 0	10 years	2500	162,500 0 0
1750 to 1760	172,779	26,580	63 7 6	10 years	2658	168,450 15 0
1760 to 1770	177,302	27,277	66 6 8	10 years	2728	180,957 6 8
1770 to 1780	178,737	27,498	60 2 0	10 years	2750	165,275 0 0
1780 to 1790	192,295	29,583	68 2 0	10 years	2958	201,439 8 0
1790 to 1800	210,928	32,450	73 1 0	10 years	3245	227,047 2 6

From this table we may obſerve a regular increaſe in the quantities raiſed, the improvements in mining which took place having contributed, without doubt, to produce this effect. The price of the metal did not advance in proportion to the increaſe of the charges on labour, and the enhanced value of the articles uſed in the mines, and therefore we cannot account for the greater produce from increaſed demand, but from the power derived by improved means of working, and thus of bringing the metal to market at a cheaper rate. About the year 1770 the quantity raiſed appears to have been greater than the demand required, and the price ſeems to have been lower than at any former period, which was probably likewiſe affected by the war, and by the influx of tin imported into Europe by the Dutch from their poſſeſſions in the Eaſt Indies, where it is raiſed as well as in England. The advance in price that followed in the next period, may be attributed to the revival of trade, in conſequence of the peace which followed the American war, but this again produced an over quantity in the market, followed by a depreſſion in value, very injurious to the miners, which was ſeverely felt about 1789, when, by the exertions of Mr. G. Unwin, an export of tin to China, through the Eaſt India company, took place, that abſorbed the ſurplus which the European market did not require, and thus the price advanced again to a rate higher than any preceding one. This export to India has continued ever ſince, and may probably increaſe notwithſtanding that tin is found in ſome conſiderable quantity in Aſia.

From 1800 to the preſent time the tin mines of Cornwall have rather declined, and are probably gradually exhauſting, this metal not being found to penetrate ſo far into the earth as copper, and therefore but few mines have been found to continue productive at very conſiderable depths.

Any decline that may have taken place in the tin mines of Cornwall has, however, been more than compenſated by the

rapid advances which the copper mines have made in that and the neighbouring diftrict, which of late years have been fo great as to render them of the higheft confideration, and to give thefe concerns the precedence over all fimilar undertakings of any country. For whether we confider the quantity of their produce, the immenfe capitals invefted, the power and number of their engines, the fkill with which they are conducted, or the fpirited and rapid execution of the works, they will probably be found to take the rank here affigned to them.

Cornwall poffeffes many eminent advantages as a mining country, of which its maritime fituation is among the moft important, but another is that it is peopled by a race of men peculiarly fitted for this employment. The Cornifh miners unite great courage to perfonal ftrength and activity, while we may obferve in their character intelligence mixed with perfevering enterprize, and patience of fatigue with a confiderable independence of fpirit.

There is no doubt but that the fyftem of management adopted in the mines, which long ufage has matured into a fyftem as beneficial to the mine owners as ftimulating to the exertions of the workmen, has tended much to render the latter what they now are, though their infulated fituation has likewife probably preferved to them much of their original character as a people.

With fuch advantages, and with a fufficient quantity of the metallic ores diftributed throughout it, a diftrict only requires capitalifts of fufficient wealth, intelligence, and enterprize, to render it of confequence as a mining country, and it has happened to Cornwall to have gentlemen poffeffed of all thefe requifites.

The ftatements which follow will fhew how the difcovery of a valuable metal has been followed up, and an intimate acquaintance with the Cornifh mines would prove how great the exertions muft have been, to have produced effects in a fhort time which the labour of ages in other countries have fcarcely equalled.

We have before obferved that copper began to be fought after in Cornwall about the beginning of the eighteenth century, and, as might be expected, we have no exact accounts of the fuccefs of the undertakings for its purfuit in their earlieft ftage. In a few years, however, the quantity produced had attained to a confiderable amount, and we fhall be enabled to trace pretty accurately the progrefs afterwards made.

The firft document on the fubject is the following:

Statement of the Returns of Copper Ores in Cornwall, from 1726 to 1775.

Years.	Tons of Ore.	Average Price *per* Ton.	Amount.	Annual Quantity of Fine Copper.
		£ s. d.	£	(Probably)
1726 to 1735	64,800	7 15 10	473,500	700 Tons.
1736 1745	75,520	7 8 6	560,106	830
1746 1755	98,790	7 8 0	731,457	1080
1756 1765	169,699	7 6 6	1,243,045	1800
1766 1775	264,273	6 14 6	1,778,337	2650

This account is taken from Pryce's "Mineralogia Cornubienfis," excepting the laft column of the quantities of metal produced from the ores, which it was defirable to exhibit, in order to compare the increafe of late years, of which the quantity of *fine copper* is the only true criterion, the ores often differing materially in their metallic content. The ftatement is, however, given as refpects this part of it only as a near approach to the truth, as we have no certain data to calculate from; the affay and price of copper, by which the value paid to the miner was determined, being in a great part of the period above quoted not eafily afcertained. The amount of metal is, however, calculated from the moft probable fuppofition.

From the table we fee, that in Cornwall the produce of copper increafed in fifty years from about 700 tons of fine metal *per annum* to 2650 tons.

Copper mines were not attended to in England much before the dates in the preceding table, the difcovery of this metal probably having taken place in working the tin mines, which had been wrought time immemorial. Soon after that difcovery, in 1691, a charter was granted to fir Jofeph Herne and others, merchants of London, who were thereby incorporated as a company for the purpofes of refining and purifying copper ores.

This company ftill exifts, and is now commonly called the Englifh Copper Company.

The Mines Royal Company, which had been incorporated near 100 years before this time, appear originally to have defigned to apply their refources to the opening and working mines in various parts of the kingdom, and they had grants for fearching for copper among other metals, although it does not appear that any important difcovery of this metal took place in confequence of their exertions, nor is mining one of thofe purfuits which is ever likely to flourifh in the hands of large companies.

In 1694, a copper coinage of halfpence and farthings took place, and government paid at the rate of 18*d.* a pound for the copper, which was of Swedifh produce.

In 1717, a further coinage took place, to the amount of 700 tons of Englifh copper, for which government paid at the rate of 15¾*d.* *per* pound, or 147*l.* *per* ton.

In 1702, the firft brafs work in England was erected near Briftol, which has continued to this time, but with great additions and improvements. Many other copper and brafs houfes have been fince erected in this country, and by that fpirit, energy, and enterprize, for which the people of it are fo diftinguifhed above all others, the moft valuable branches of the copper and brafs trade have been eftablifhed in England, which had before been altogether, and for ages, carried on in Germany and Holland.

For the firft twenty or thirty years of the laft century, and always before, moft of the copper and brafs utenfils for culinary and other purpofes of this country were imported from Hamburgh and Holland, procured from the manufactories immemorially eftablifhed at Nuremberg and various other parts of Germany; even brafs pans for the purpofes of the dairies of our country could not be procured but of the German make.

So late as 1745, 1746, and 1750, copper tea-kettles, faucepans, and pots of all fizes were imported here in large quantities from Hamburgh and Holland; but through the perfevering induftry, capitals, and enterprifing fpirit of our miners and manufacturers, thefe imports became totally unneceffary, being all made here, and far better than any other country could produce.

During all this time the price of copper will be found to have been as high as it has been in the laft three or four

years, 1808, 1809, 1810, and 1811, notwithstanding the great difference in the value of money, and consequent advance of price on materials used in mining, and of the wages of labour employed therein.

It appears above that government paid for copper used in their coinages in the year 1694 at the rate of 18*d.* a pound, or 168*l.* a ton for metal the produce of Sweden; and in 1717, they were supplied with English copper at the rate of 15¾*d.* a pound, or 147*l.* a ton.

The reduction here specified in value may fairly be accounted for by the increasing produce of the English mines, and accordingly the price went on to lower nearly in proportion to the quantity which was thus brought into the market.

In the year 1720 copper was sold for about 130*l.* a ton, and declined towards the year 1772 to the price of 100*l.* a ton.

About the year 1773, new copper mines being discovered in Derbyshire and Wales, and fresh supplies of fine copper coming from thence to market in competition with the Cornish copper, the price of it fell gradually until 1781. In this year the East India company first paid so little as 79*l.* a ton for cake copper. This great reduction was owing to a warm contest which took place between the owners of the Cornish mines and those of the Paris Mountain mine in Anglesea, which had become amazingly productive, and so as to alarm the fears of the former.

Arrangements were afterwards made between the parties principally concerned in the mines of these two districts, by which the price was somewhat advanced, but did not exceed at any time 84*l.* a ton, and continued at nearly the same rate until the year 1791.

By this time England, instead of depending upon foreign mines for a supply of copper, had become one of the principal sources from which the world at large was furnished with this useful metal.

Accordingly, in the year 1791 we find that the exports of different articles in which copper either formed the whole or the principal ingredient, amounted to a very considerable branch of trade, and that these articles went in large quantities to those very countries upon which England had formerly depended for a supply. Among these may be noticed Holland, Germany, and even Sweden itself.

The total exports were, in 1791,

	Tons.	C.	qrs.	lbs.		£	s.	d.
Wrought copper	3082	3	3	11	value	358,844	9	1
Brass and plated goods	2324	2	0	11		209,769	8	9
	5406	5	3	22		568,613	17	10

Comparing this with the produce of copper in Cornwall in the year 1775, as above quoted from Dr. Pryce, which was only 2650 tons, and allowing for what might be brought to market from Anglesea, we may, in some measure, judge of the increase in the quantity of metal from the Cornish mines in this period of sixteen years, even under the discouraging circumstance of great competition and reduced prices.

Besides this vast export, a new source of consumption for copper had in the mean time arisen at home in the use of it very extensively in sheathing and fastening ships, and this alone would require considerable quantities.

The demand having apparently kept pace with the quantity brought to market, the question will naturally be asked, how it happened that the price continued to fall, or at least to remain at a rate so much under what it brought 100 years before? Though the answer to this question must include other considerations than those connected with mere mining, it may be proper to go a little out of our way to answer it, particularly as it relates to the mines of Cornwall, which were at one time threatened almost with ruin, from the value of their produce not bearing any proportion to the increase in their expences, from the diminished value of money, and the rapidly accumulating charges occurring from the great depths to which most of the productive mines were by this time worked.

The reason, then, of the price of copper not bearing a proportion to the cost of procuring it, and the demand of the article, appears to have been simply this. Neither the miners nor the great consumers of the copper were smelters of the ore; but this business was in the hands of a very few companies, employing immense capitals in their works, who thus had the power of managing the market, and of preventing that salutary competition, which alone can regulate fairly the due course of trade.

The principal smelters, by a contract which had been entered into improvidently with them by the majority of the miners, had possessed themselves of the greater part of the copper ores of the county of Cornwall at a fixed price; and this price being found inadequate to meet the increasing charges of working the mines, discontents arose, which spread among the labouring miners, who feared the loss of their employ by the ruin of the mines, which was anticipated. Many of the proprietors, or adventurers as they are usually called, who were not personally parties to the contract, refused to be bound by the act of their co-adventurers, and considerable confusion ensued.

The small proportion of the ores, not included in the contract, continued to go to public sale, where the price was advancing; but these sales were attended by a few smelting companies only who had not joined the others, until the following circumstance occurred, which materially contributed to open a free market to the miner for the sale of his ores, upon a plan that ensures a fair and equitable price, according to the demand, as far as is possible, where the number of buyers must be necessarily small.

Many of the principal manufacturers of Birmingham, who were large consumers of copper, had observed the difference between the price of the metal in the ore paid to the miner, and the price at which they bought it when smelted. They saw no other reason for the intervention of a third party between the miner and consumer, but the capital necessary for the erection of smelting works; and this being easily raised by shares, a company was formed under the name of the Birmingham Mining and Copper Company: their object being to encourage the production of copper, by adventuring in the mines, as well as to procure it for their manufacture, by purchasing and smelting the ores.

As soon as the company was established, they proposed to revive the old mode of the sale of ores, which had, owing to the contract, nearly fallen into disuse, called a *ticketing*; by which, on certain days, the ores of any number of mines, being previously sampled and assayed, are offered for sale by tenders or tickets, produced by the agents of each smelting company, and delivered to the chairman of the meeting which is held for the purpose, who declares the offer of each, and the highest the buyer.

This revival of the ticketings was effected by the Birmingham company joining the small number of smelting companies who were not concerned in the contract, and the competition was rendered complete. A new spirit was infused into the working mines, by an increase of the price of their produce. Other smelting companies were afterwards formed upon similar principles; and the demand for copper advancing rapidly, while the quantity produced in Anglesea and other parts of England lessened, the mines of Cornwall flourished in proportion.

The advance on copper began to be felt about 1792, when it had attained the price of 100*l.* *per* ton; and in a very few years after (1799), it had reached 124*l.*: being ftill, however, much lower than it was in the beginning of the 18th century.

We may recollect that the quantity of copper raifed in Cornwall, in the year 1775, was about 2650 tons a-year: in 1789 it had increafed to about 3000 tons; which increafe was progreffive, as in the year 1797, according to the report laid before the houfe of commons, the quantity amounted to 5093 tons; and in the following year (1798), was 5427 tons.

So that we fee in the period of about 70 years from 1726, the annual quantity produced by this diftrict had rifen from 750 to 5427 tons; and that the aggregate amount of an article, valuable as a raw material, affording, after it paffes from the hands of the miner, the means of fubfiftence and profit to thoufands, had rifen from the fum of 47,350*l.* to about 600,000*l.* a-year. Even this great increafe of produce was far exceeded in the courfe of the next eight or nine years, when, as we fhall fee heareafter, half as much more was added to the quantity, and more than that proportion to the value.

Early in the year 1799 the Birmingham manufacturers, finding the price of copper rapidly increafing, began to be alarmed left a diminution of their trade fhould be the confequence, and having apparently overlooked the plain rule of commerce, that, without unfair reftraint, demand muft govern price, applied to government to impofe prohibitions on the export, and other regulations, which would have amounted in effect to the fixing a maximum on the price, and confequently a ruinous reftraint on a valuable fource of national wealth, and laudable enterprife and exertion. It may be juftly wondered at, that any miniftry fhould have liftened to fuch a propofal; but great as were the boafted talents of the then premier, he appears to have been led to the warm fupport of it, by the narrow confideration which was held out to him, of fupplying the navy with copper at a fomewhat lower price; not looking forward to the probability that any ftep which might ruin the Britifh copper mines, muft eventually make the Britifh navy dependent on other countries for this effential article of equipment.

The conteft that enfued between the miners and the manufacturers produced many curious documents, which were laid before the committee of the houfe of commons appointed to inveftigate the fubject, and from which we are now enabled to ftate particulars of the mines of Cornwall, more exactly than could have been obtained, had not fuch an occafion called them forth.

The matter came fully before parliament, the good fenfe of which defeated the impolitic wifhes of the propofers of the reftrictions, and left a miniftry unaccuftomed to defeat in a minority on the queftion.

That the predictions of the manufacturers were groundlefs may be inferred from what took place afterwards: the price of copper advanced 50 *per cent.* in the next feven years, and the Birmingham trade, notwithftanding, increafed in activity and confequence. The high price ftimulated the enterprife of the miner, until an over-fupply began to operate; and in the laft few years, this, together with the unfortunate ftate of foreign trade, has again reduced the price of copper, fo as once more to endanger the exiftence of a great proportion of the copper mines.

From the documents before alluded to, we find that, in February 1799, there were in Cornwall then working fixty copper mines, which were divided into claffes, to fhew their relative conditions. The accounts are made up for the fix months preceding the ftatement.

Clafs 1. Includes the old deep mines, which produced in the fix months more than half of all the copper raifed in Cornwall.

2. Includes the profitable mines, which produced about three-eighths of the copper.

3. The new mines which were carrying on in the hopes of their improvement, and the greater number of which, in fact, had not begun to yield any ore.

The refult of the ftatement is as follows, in which it is to be obferved that the value of the ores is accounted for, after deducting the proportion paid to the owner of the foil, and therefore does not exhibit an account of all that was raifed. The firft column of lofs refers to the money funk in the fix months for which the account is taken; and the laft column of unrecovered lofs includes all the money laid out from the commencement of each mine, which had not been paid off by adequate returns.

State of the Copper Mines of Cornwall for fix Months, to the end of February 1799.

	Quantity of fine Copper.				Adventurers' Amount of the Value.			Coft of working the Mines.			Total of Profit on fome Mines.			Total of Lofs on others.			Capital employed in the Mines.			Unrecovered Lofs.		
	Tons.	C.	q.	lbs.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Clafs 1.—Including ten old and deep mines -	1388	3	1	21	115,121	13	10	116,209	1	6	3153	0	3	4240	7	11	102,489	0	0	69,181	2	10
Clafs 2.—Seven profitable mines -	1083	12	2	24	86,377	15	3	49,311	11	1	37,066	4	2				66,813	0	0	5483	17	2
Clafs 3.—Forty-three new mines, of which thirteen only had begun to raife any ores -	141	17	1	13	14,517	13	3	31,813	5	9				17,295	12	6	16,267	0	0	90,124	16	8
	2613	13	2	2	216,017	2	4	197,333	18	4	40,219	4	5	21,536	0	5	185,569	0	0	164,789	16	8

By this ſtatement we ſee, that the total profit of the ſix months, in all the mines, exceeded the loſs by the ſum of 18,683*l.* 4*s.* 0*d.*, and in the loſs is included a conſiderable amount, which it does not ſeem clear ſhould have been placed there, *viz.* the ſums expended on the new mines in the period, as this may more properly be called an inveſtment of capital with a view to future expected profit.

The unrecovered loſs is ſubject to the ſame remark, though it is uſual to reckon in mining the expenditure as loſs until the profits have repaid it. The capital, however, which means the value of ſtock upon the mines, ought to be deducted from this unrecovered loſs; and if this be done, and a fair allowance be made for the value of ſuch new mines as might have been ſuppoſed likely to become profitable, the account gives no unfavourable impreſſion of the general reſult at that time.

Another obſervation may be made on this account which ſeems neceſſary, as it does not appear on the face of it. Credit is only given for the adventurers' part of copper ores; but ſeveral of theſe mines returned tin as well as copper, of which no account is taken, and which muſt, in all probability, have increaſed the profits of the ſix months, if ſtated.

The next table ſhews the general receipts and diſburſements on the copper mines of Cornwall for ſeven years, ending the 31ſt December, 1798, which cannot be deemed ſo favourable as the former, which related to the latter part of this ſame period.

General State of the Copper Mines of Cornwall for Seven Years, ending the 31ſt of December, 1798.

Years.	Adventurers' Amount of Ores.			Labour.			Materials.			Total Coſt.			Profit.			Loſs.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
1792	279,331	15	10	150,824	12	3	91,361	6	4	251,865	19	11	27,465	15	11			
1793	283,853	12	11	176,333	2	7	110,122	15	2	294,226	15	0				10,373	2	1
1794	293,853	10	11	179,187	15	5	111,093	19	11	294,775	19	5				922	8	6
1795	305,320	6	9	189,713	10	1	111,640	2	3	312,047	7	5				6727	0	8
1796	348,836	12	11	201,995	18	6	105,925	12	1	324,897	18	4	23,938	14	7			
1797	320,606	15	9	189,821	15	11	109,008	7	3	309,060	14	10	11,546	0	11			
1798	405,488	15	9	253,601	12	3	146,253	16	3	408,248	7	11				2759	12	2
	2,237,291	10	10	1,341,478	7	0	785,405	19	3	2,195,123	2	10	62,950	11	5	20,782	3	5

N. B.—The columns of labour and materials, added together, do not make up the total coſt, becauſe the accounts ſent from ſome mines do not diſtinguiſh the amount of labour from materials; and, therefore, could be no otherwiſe arranged than by being carried at once to the column of total coſt.

The average annual coſt of working the copper mines of Cornwall for this period appears to have been 313,589*l.* Out of this ſum the labour appears to have coſt about 197,640*l.*, and the materials employed about 115,950*l.* The proportion of the one to the other being nearly as 5 to 3.

The great amount of the latter may be attributed to the great depth of many of the mines, whereby the charge for coals for the ſteam-engines, and the wear and tear in the ſhafts of cordage and other articles, is prodigiouſly increaſed.

If, taking the amount of labour at the above ſum, we allow 40*l.* as the annual earnings of each man employed, which is nearly the uſual proportion, we ſhall find it would ſhew that there are about 5000 men employed. But as a certain proportion belongs to the boys working under ground, and the women and children who dreſs the ores on the ſurface, who altogether are paid after a much lower rate, the whole number of hands, including men, women, and children, may not, at this period, perhaps be over-rated at from 6 to 7000.

In order to ſhew the reſpective ſtate of each mine at this time, we inſert the following table, which exhibits the name of each, with the particulars of their expenditure and returns, as far at leaſt as copper is concerned; for, as was remarked before, no notice is taken of the tin produced from any of them.

We take the year 1798, the laſt of the ſeven years to which the ſtatement given above refers to.

Such is the fluctuation of concerns of this ſort, that at the preſent time, 1812, very few of thoſe which appear at the head of the following liſt as moſt important in conſequence and produce, are now working to much extent, while others, which either then lay neglected, or in which diſcoveries had not been made, have ſucceeded to ſupply their places.

State of the Copper Mines in Cornwall for the Year 1798.

Mines.	Adventurers' Amount of Ores			Labour.			Materials.			Total Coſt.			Profit.			Loſs.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
North Downs -	52,388	14	6	33,350	2	1	18,890	19	9	52,241	1	10	147	12	8			
United Mines -	36,194	8	4	20,196	0	3	20,241	19	3	40,437	19	6				4243	11	2
Conſolidated Mines	35,613	11	10	21,547	4	2	10,877	14	0	32,424	18	2	3188	13	8			
Herland -	29,233	10	9	16,922	2	0	13,789	11	6	30,711	13	6				1478	2	9
Stray Park and Wheal Gons	12,125	10	10	6660	11	0	3182	13	0	9843	4	0	2282	6	10			
Poldice -	6993	19	9	4945	19	3	5677	3	1	10,623	2	4				3629	2	7
Wheal Unity -	41,330	8	7	10,851	2	5	13,510	17	10	24,362	0	3	16,968	8	4			
Crenver and Oat-field -	19,429	14	7	9392	10	2	10,016	9	11	19,409	0	1	20	14	6			
Wheal Treaſury -	19,978	4	10	20,050	18	8	5541	4	2	25,592	2	10				5613	18	0
Cook's Kitchen -	18,098	5	4	16,102	2	4	3468	13	7	19,570	15	11				1472	10	7
Wheal Rock -	995	19	7	1533	5	6	417	10	4	1950	15	10				954	16	3
Tin Croft -	35,242	17	1	15,233	10	2	6105	4	3	21,338	14	5	13,904	2	8			
Treſavean -	7609	2	9	5437	1	9	3069	2	3	8506	4	0				897	1	3
Prince George -	12,538	16	5	9045	3	5	1068	4	0	10,113	7	5	2425	9	0			
Camberne Vean -	6456	17	3							2885	1	2	3571	16	1			
Wheal Jewel -	19,035	18	2	10,710	6	8	5311	3	3	16,021	9	11	3014	8	3			
Pednandrea -	5078	7	10	10,587	16	8	7287	9	1	17,875	5	9				12,796	17	11
Wheal Fortune -	20,767	0	3	9450	18	7	2560	13	10	12,011	12	5	8755	7	10			
Wheal Gorland -	9032	0	8	3975	17	0	1893	19	5	5869	16	5	3162	4	3			
Wheal Providence	257	8	0							252	7	4	5	0	8			
Wheal Hope -				400	3	6	247	9	6	647	13	0				647	13	0
Scorrier -	102	14	6	509	10	6	103	14	7	613	5	1				510	10	7
Cherry Garden -	22	13	9	321	3	0	56	11	11	377	14	11				355	1	2
Wheal Suſan -	1407	8	9	1956	13	0	1465	1	8	3421	14	8				2014	5	11
Wheal Squire -										820	3	7				820	3	7
Eaſt Wheal Spar-non -				356	6	3	45	10	5	401	16	8				401	16	8
Drollas Downs -	1075	14	7	1847	5	11	41	19	2	1889	5	1				813	10	6
Wheal Captain -	643	9	9							1617	16	7				974	6	10
Creegbraws -	77	3	10	1054	7	3	154	18	6	1209	5	9				1132	1	11
Weſt Wl. Unity -										83	19	9				83	19	9
Wheal Penroſe -				108	6	8	12	0	2	120	6	10				120	6	10
Wheal Tremayne				127	14	5	2	19	0	130	13	5				130	13	5
Wheal St. Aubyn				53	19	10	15	1	3	69	1	1				69	1	1
Roſe Lobby -				270	7	8	138	9	5	408	17	1				408	17	1
Heart's Eaſe -				273	13	8	4	19	10	278	13	6				278	13	6
Boſprowall -	1377	11	3	1413	1	0	398	5	2	1811	6	2				433	14	11
Druid -	17	18	11	421	12	4	264	5	1	685	17	5				667	18	6
Wheal Fanny -				640	16	4	468	19	6	1109	15	10				1109	15	10
New Roſkeir -	475	19	3	1106	9	3	1280	1	2	2386	10	5				1910	11	2
Polgine -										1220	3	9				1220	3	9
Wheal Chriſtoe -				43	7	10	10	19	0	54	6	10				54	6	10
Wheal Drim -										56	16	5				56	16	5
Dopps -	15	10	0	241	12	7	31	9	10	273	2	5				257	12	5
Nanjiles -				71	3	7	18	18	0	90	1	7				90	1	7
Weſt Downs -				612	2	10	187	13	2	799	16	0				799	16	0
Wheal Abraham -				1618	11	5	815	18	5	2434	9	10				2434	9	10
Weſt Good Succeſs				156	12	2	34	7	9	190	19	11				190	19	11
Whiteſield -				418	3	6	198	5	4	616	8	10				616	8	10
Wheal Pink -										118	18	9				118	18	9
Penſtruthell -				195	11	2	33	18	7	229	9	9				229	9	9
Wheal Damſel -				373	14	5	101	16	5	475	10	10				475	10	10
Wheal Quick -	121	17	7	537	9	5	204	13	2	742	2	7				620	5	0
North Good Succeſs				81	0	5	1	6	7	82	7	0				82	7	0
Carried over	393,738	19	6	241,203	12	0	139,250	5	1	387,509	4	5	57,446	4	9	51,216	9	8

Mines.	Adventurers' Amount of Ores.	Labour.	Materials.	Total Coſt.	Profit.	Loſs.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
Brought over	393,738 19 6	241,203 12 0	139,250 5 1	387,509 4 5	57,446 4 9	51,216 9 8
Wheal Bounty -		122 9 10	61 11 4	184 1 2		184 1 2
Wheal Rachel -		123 6 5	20 1 9	143 8 2		143 8 2
Wheal Royal -				66 16 1		66 16 1
Wheal Clinton -		60 2 0	38 9 8	98 11 8		98 11 8
Tolcarne -	641 6 1	1248 0 9	532 12 4	1780 13 1		1139 7 0
Weſt Tolcarne -	13 4 8	98 3 2	24 13 8	122 16 10		109 12 2
Wheal Union -		102 14 0	20 10 6	123 4 6		123 4 6
Eaſt Wheal Vogue		71 15 4	17 3 0	88 18 4		88 18 4
Wheal Spinſter -		36 2 6	4 5 4	40 7 10		40 7 10
Treſkerby -		111 8 4	14 16 3	126 4 7		126 4 7
Cardrew -	30 2 6	212 2 0	23 14 0	235 16 0		205 13 6
Wheal Leeds -	39 6 4	430 19 9	447 11 5	878 11 2		839 4 10
Trenethick Wood				685 6 5		685 6 5
Wheal Muttral -	639 9 8	641 17 8	18 2 11	660 0 7		20 10 11
Treſkow -	7495 14 8	5375 19 8	2576 18 10	7952 18 6		457 3 10
Penberthy Crofts	281 2 9	1912 0 6	686 8 3	2598 8 9		2317 6 0
Wheal Kayle -		135 17 3		135 17 3		135 17 3
Eaſt Wheal Park		345 5 6	160 6 0	505 11 6		505 11 6
Wheal Ruth -		136 9 5		136 9 5		136 9 5
Wheal Carpenter				53 1 11		53 1 11
Wheal Chance -				226 14 0		226 14 0
Weſt Wheal Jewel	1551 17 5	1243 6 2	2356 5 11	3599 12 1		2047 14 8
Wheal Bog, ore and materials ſold	1057 12 2			295 13 7	761 18 7	
	405,488 15 9	253,611 12 3	146,253 16 3	408,248 7 10	58,208 3 4	60,967 15 5

About this period a part of the county of Devon began to attract notice as a mining diſtrict, although it might rather ſeem to belong to Cornwall, if a diviſion had been made between the counties by a line that an obſerver of the geology would have chalked out, rather than by the arbitrary limit of a river. The mines of Devon may, therefore, fairly be ranked as a branch of the great mineral country adjoining, as their features are nearly alike, the products very ſimilar, and the ſyſtem of working derived from Cornwall. A ſpace of no inconſiderable extent indeed is to be found lying between the weſtern and moſt conſiderable mines in Cornwall, and thoſe on its eaſtern limits, which intervening tract is comparatively unproductive in mineral treaſures.

The tin mines of Devon have been before alluded to, and we have ſeen that they had gradually declined into inſignificance. Copper had now been found, and purſued with ſome ſucceſs, and though the quantity was not very great at this period, it ſoon led to greater exertion, which in turn was repaid by the diſcovery of new mines and an enlarged return of valuable produce.

It is probable that before 1800 the mines of Devon, which are moſtly ſituate within a few miles of the town of Taviſtock, did not yield more in any one year than about 100 tons of fine copper, and even this was a very recent diſcovery; we ſhall now ſee that they went on, together with thoſe of Cornwall, augmenting in importance.

From 1798 to 1804, the produce of the Corniſh mines appears to have continued pretty ſteadily at about 5500 tons of fine copper a-year; while the Devon mines in the ſame period increaſed their returns very rapidly, which had reached, about this time, to about 300 tons of fine copper a-year.

The price of the metal we mentioned to have been, in 1799, about 124*l.* a ton, and until 1804 a gradual increaſe was experienced, although the ſupply was at leaſt ſomewhat larger. In the following year, however, owing to the flouriſhing ſtate of the export trade, the value of copper roſe very rapidly, and reached the unprecedented price of 180*l.* a ton to the miner. The conſequences of this were ſoon felt, and, by the exertion produced by this ſtimulus, the returns of the Corniſh and Devon mines reached to more than 7000 tons of fine copper, fetching, at the firſt hand, the ſum of 1,260,000*l.*

From this time to the preſent, the value of copper has experienced violent and rapid fluctuations, being, at one time, at half the price of the year 1805; and as this has proved a cauſe of great embarraſſment and loſs to the adventurers in the mines, ſo it has tended to reduce again the quantity of copper raiſed.

The year or two following 1805 were, as might be expected, even more productive than that in which the price attained its higheſt pitch, for the exertions it cauſed operated long after the price began to decline.

The following Table exhibits a Statement of the Quantity of Copper Ores and Fine Copper produced by the Mines of Cornwall and Devon during the last four Years, taken up to the End of June in each Year, and the Value calculated according to the Average Standard, or Miner's Price of the Metal.

		Copper Ores.			Fine Copper.				Average Standard *per* Ton.			Annual Amount after deducting Charges of Smelting.		
		Tons.	cwt.	qrs.	Tons.	cwt.	qrs.	lbs.	£	s.	d.	£	s.	d.
1808	Cornwall -	73,434	2	1	7118	5	1	17						
	Devon - -	3725	0	0	369	10	0	0						
		77,159	2	1	7487	15	1	17	107	0	0	781,348	16	7
1809	Cornwall -	72,038	12	2	6972	17	0	24						
	Devon - -	3210	0	0	365	1	3	0						
		75,248	12	2	7337	18	3	24	122	0	0	875,784	2	3
1810	Cornwall -	76,525	14	3	6651	18	2	5						
	Devon - -	3713	0	0	354	15	0	0						
		80,238	14	3	7006	13	2	5	141	0	0	969,376	19	0
1811	Cornwall -	70,039	0	1	5948	7	0	22						
	Devon - -	3540	0	0	323	13	0	0						
		73,579	0	1	6272	0	0	22	125	0	0	767,379	4	0

We have now brought the history of the copper mines up to the present period, and we have found what has been done in one district in the space of about 100 years after the discovery of the metal. We may observe, that in the beginning of the 18th century the annual produce of the mines consisted of about 6500 tons of ore, and 700 tons of fine copper, yielding to the miners, who, from their ignorance of the subject, did not then receive from the smelters a price for their ores adequate to the value of the metal they contained, no more than 45,000*l.* a-year. And we have found this produce increased, at the early part of the present century, to the annual quantity of near 80,000 tons of ore, yielding more than 7000 tons of fine copper, worth to the miners an annual sum little short of 1,000,000*l.*

The copper mines now working in Cornwall and Devon may be known from the following list, which contains such only as are more or less productive, and does not include such as make no returns, but may, notwithstanding, be prosecuting with a view to future discovery, many of which kind were stated in the former account of the mines working in Cornwall in 1798.

By referring to that statement, we shall find the productive mines to be forty in number, and the unproductive to amount to thirty-six.

The following list will be found to contain sixty-one productive mines, with the quantity of ores estimated from the account of sales at the ticketings, where the computed weight of each parcel of ore is stated, and the exact quantity determined after the sale has taken place.

It is possible that some few mines may exist which do not appear in this list, and which sell their ores by private contract, but they are not important.

We subjoin to the list the Devon mines, with their quantities of ore, taking account, as in Cornwall, of such only as are productive; and the whole is made up to the end of December 1811.

A list of Copper Mines, with the Quantities of Ore offered for Sale at the Ticketings from each, in the Year 1811.

In the county of Cornwall there are 61 mines.

Names of the Mines.	Tons of Ore.
Wheal Alfred -	
Dolcoath -	
Wheal Unity -	
Wheal Abraham -	
Poldice -	
Wheal Damsel -	
Gunnis Lake -	
West Wheal Fortune	
Wheal Towan -	
Wheal Fanny -	
Crennis -	
Oatfield - -	
Treskirby -	
Wheal Gorland -	
Cook's Kitchen	
Crenver -	
Tin Croft -	
North Downs -	
Wheal Friendship	
Wheal Jewel -	
Wheal Virgin -	
Saint George -	
United Mines -	
West Wheal Virgin	
Wheal Fortune -	
Wheal Quick -	
Camborne Vean -	
Wheal Chance -	
Wheal Spinster -	
Carried over	63,636

Brought over	63,636	
Wheal Neptune - - -	539	
Wheal Gons - - -	443	
Godolphin - - -	411	
Creegbraws - - -	316	
Trefavean - - -	311	
Nangiles - - -	266	
Botallack - - -	244	
Penberthy Crofts - -	212	
Wheal Clinton - - -	209	
Chacewater - - -	204	
Wheal Baffett - - -	204	
Wheal Dolphin - - -	183	
Wheal Druid - - -	177	
United Hills - - -	177	
Benner Downs - - -	175	
Wheal Maid - - -	151	
Wheal Strawberry - -	148	
Union - - -	146	
Wheal Mufic - -	145	
Wheal Sparnon - -	97	
Wheal Maudlin - - -	95	
Wheal Margaret - - -	90	
Wheal Lufhington - -	81	
Unanimity - - -	49	
Wheal Squire - - -	45	
Reliftian - - -	41	
Wheal Spearn - -	20	
Wheal Mary - - -	20	
Trenowith - - -	18	
Wheal Freedom - - -	16	
Rofkear - - -	10	
Rofewarne - - -	7	
		68,886
In the county of Devon feven Mines.		
Wheal Friendfhip - -	1102	
Wheal Crebor (*Tavifiock Canal*)	1308	
Wheal Crowndale - -	863	
Eaft Crowndale - - -	913	
Ding Dong - - -	250	
Wheal Hope - - -	6	
Wheal Huckworthy - -	10	
		4,452
	Tons	73 338

Hence it will appear, that the copper mines have of late been declining in their produce, which is to be referred to the general ftate of trade rendering the price of the metal unequal to the charge of producing it.

The prefent value of copper, as was obferved in a former part of this article, is as low as it was 100 years ago, and we may account for the poffibility of this happening without abfolute ruin to the mines, by the facilities which the great improvements in all the various operations of mining have given for leffening manual labour and confequent expence.

This very improvement has, however, contributed to a more rapid exhauftion of the ores, and though difcovery has hitherto in this diftrict kept pace with the gradual wafte, yet it is impoffible not to forefee that as the country is even now very fully explored, a time muft arrive when the quantity of metal produced will grow lefs, and the price in confequence muft advance.

This period we conceive is not fo diftant as fome may imagine, but it is a fubject not eafily reduced to any very probable calculation.

The hiftory of the mining of a particular diftrict would naturally lead to an interefting enquiry on this fubject, and to the difcuffion on the probability of a future and continuing fupply of the metals which the bowels of the earth have hitherto yielded fo abundantly. As this queftion regards one country, it may be affumed that the fupply muft have its limits; as it regards the whole world, it becomes difficult even to conceive what extent or number of depofits of metal may exift.

That certain diftricts may become exhaufted is more than probable, but others now unexplored by the hand of man may be found. New powers, as far furpaffing thofe of the fteam engine as they did all former ones, may give the means of penetrating the earth to depths now unattainable, and veins may hereafter be followed to fituations which are forbidden at prefent by the value of their produce or the want of fufficient exertion.

The ftores which the earth yields from its bowels are unlike thofe which its furface produces; the former are limited and are not renewed, the latter are conftantly produced by the encouraging hand of induftry. The one are gradually exhaufting, and feem to demand frugality in their expenditure, the other grow and increafe in proportion to our care and exertion.

The refult of a gradual exhauftion of mines now exifting feems likely to be this; at firft the price of metals will increafe in proportion to their fcarcity, this advance in value will lead to a greater produce by new efforts even in the diftricts which are exhaufting, and after thefe begin again to fail, which they will do more rapidly from the increafed exhauftion, new diftricts will be fought after, and perhaps uncultivated countries even become peopled by the want of what is now become fo neceffary to human life.

The variation in thefe affairs may at fome time make material changes in the ftate of civilization, a pofition which will not be denied by thofe who duly confider the effects that the ftores of coal and metal have had on the profperity of Britain.

MINING *Proceffes*, according to the practice of the mineral diftricts of Cornwall and Devon.

The means purfued for the difcovery of veins containing metal, and the appearances which ferve as indications of the probable quantity which may be found in them, are treated of in a former article. See LODE.

The works which follow the difcovery are at firft but fimple and limited, but they increafe afterwards in proportion as the profpects of future fuccefs become more certain; or, on the contrary, they are difcontinued when the trial offers but little encouragement to proceed with the adventure.

By a reference to the article above quoted, it will be underftood how the depofits of metal are ufually fituated in the veins; and as the miner's object in his firft operations is to get at fome fhoot or bunch of ore as quickly as poffible, and to open as much of the lode as he conveniently can, the moft promifing part on the furface is chofen for the commencement of a *fhaft*, which is either funk upon the vein fo as to follow its dip or underlay, or otherwife is carried down perpendicularly from fome fpot on the fide to which it dips, fo as to interfect it at a given depth, and then is ufually called an *underlayer*.

As water is commonly foon met with in fuch quantities as to impede the workmen, means for removing it muft be provided, and it fpeedily becomes neceffary to take fteps for this purpofe. Where the elevation of the ground will admit of an *adit* or water-level being made, this is ufually firft had recourfe to, particularly when it may be obtained by driving

a moderate distance, or when it can be pursued on the course of the lode, and so serve the double purpose of a drain and a level for trying the appearances of the vein.

When the shaft becomes deeper than the adit, or indeed when the latter cannot well be had, machinery to draw out the water is erected and employed, such as steam-engines, or overshot water-wheels where streams to drive them can be obtained: in both cases these engines are employed to work pumps to raise the water.

As soon as a shaft is sunk sufficiently deep, and it becomes desirable to pursue the lode horizontally, it is stopped for a time, and a level is commenced on each side of it, and this is usually continued in two opposite directions upon the course of the vein. The ends of this level being driven out of the way of the shaft, sinking may again be undertaken, and continued until it is deemed proper to drive another level; and thus a succession of these galleries or drifts are opened under each other, and the vein is divided into parallel portions, which are left to be worked for the ore contained therein, and which portions are called *backs*.

New openings to the surface from these levels are afterwards made by sinking more shafts at proper distances, and communications from one level to another are formed by sinking a kind of small underground shaft, called a *winze*, probably because the only machine employed in their execution for hauling the stuff is the common windlass, which, in Cornwall, has generally the same abbreviated or corrupt appellation.

When a mine is put into this state, and any quantity of ore discovered, proper engines provided with sufficient power to admit the constant deepening of the mine by keeping the bottom of the engine shaft, called the *sump*, dry, so as to be regularly sinking: when the ventilation is completed by proper means for that purpose, and machines constructed for hauling up the ores and waste to the surface called *whims*, a mine, in the technical language of Cornwall, is said to be in due course of working.

The agents who attend daily to the works are called *captains*; they contract with the different classes of miners, and direct the operations, under the orders either of the principal adventurers, or a manager appointed by them.

The shafts and levels are kept regularly sinking and driving to lead to further discovery, or to open more of the lode for working, and the parts of the vein or lode left between the passages thus made are worked away, where the ore will pay the expence of so doing, by men, who contract for this work within certain limits, being paid a proportion of the value when merchantable, which is called a *tribute*, and which varies with the degrees of facility with which the ore can be procured, either from the different states of richness of the lode, or the hardness or softness of the rock which must be broken to obtain it.

The ore is usually conveyed in wheelbarrows through the levels under ground by boys to the nearest shaft, and there raised in buckets or *kibbles* to the surface. These kibbles are wound up by the whims, which are turned either by horses, steam, or water.

In preparing the ores for smelting, a variety of processes is employed, which require the labour of many hands; these are carried on upon the surface, and chiefly by women and children. The object being to separate from the ore both the stony and sparry waste, and the mundic or other useless metallic mixtures with which it is combined, considerable skill is required, from the different specific gravities of the various substances, which render it impossible by mere washing to separate the ores entirely from the different mixtures which accompany it.

To dress ore properly, it is essential that the whole should first be brought into such a state of division, that the different parts may be separated by washing or sifting: and, therefore, the richer the state in which the whole is raised from under ground, the less the labour required in breaking or stamping. The better parts of the ore are broken to a proper size for smelting, either by flat hammers, or, as is now usual in the mines in Devon, by iron cylinders driven by water. For the coarser parts much more labour is required in stamping, sifting, and washing, the particular detail of which will be found under the article ORE.

The stamping-mills, and other apparatus for dressing the ores, are usually fixed as near the mouths of the shafts on the surface as possible, consistently with the power of leading streams of water to them. And plots, or *floors*, are prepared near them for receiving the merchantable ores until they are sold to the smelting companies.

The management of these processes is usually confided to a *dresser* or *grass captain*, who regulates the whole, the expence being borne by the men who raise the ore on tribute, who take their proportion of the value according to the amount of the sales, and, therefore, pay every previous charge.

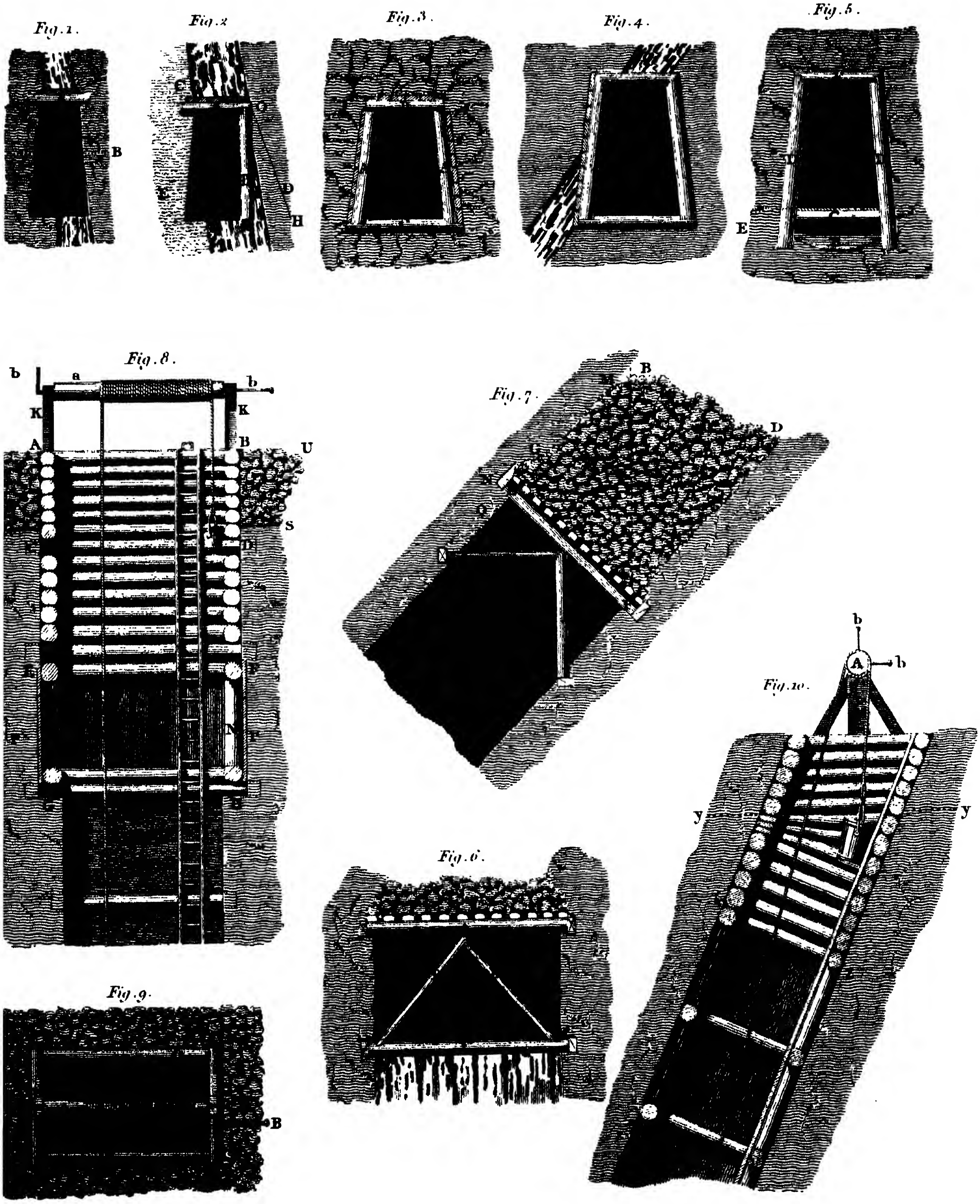
The erections on the surface of a mine comprize, besides steam or water-engines, whims, stamping-mills, and sheds on the dressing floors, a suitable counting-house for the captains and clerks, where the people are paid monthly, and the bargains or contracts made by a kind of public auction. A forge, or blacksmith's shop, accommodated to the extent of the mine, where men are generally at work by night as well as by day, to sharpen tools as well as to make or repair the iron-work of the different engines. A carpenter's shop, or *timber-house*, for work of that description, which is always going on to a considerable extent.

From the account given in the *History of* MINING, and the statement of the disbursements and returns there exhibited of all the concerns of that description in Cornwall and Devon, it may be seen how extensive some of them are in that respect. It may further be here observed that great depth has been attained in many of the older ones; in Dolcoath, which we believe is rather the deepest, the lowest part is somewhat more than 220 fathoms from the surface. Some individual mines in Cornwall employ near 1000 persons, and have several steam-engines working for the different purposes of pumping the water and raising the ore. In the county of Devon, streams of water being at hand, large over-shot wheels are employed for working the pumps, and several have been erected of late years equal in power to the larger steam-engines. Within a very late period, the same economical means have been applied in a very ingenious manner to the winding up the ores from under ground, which, from the crookedness of the shafts of copper mines, was a work of more difficulty than might at first appear.

We propose to give more detailed accounts of the processes of breaking, raising, and dressing the *Ores*, under the article bearing that title; and shall describe the operations of sinking shafts and driving the levels from them under the head of SHAFT. The pump-work of mines, and the means for ventilating drifts, will be treated of in their proper places.

MINERALOGY.

MINING



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Molosses

MOLOSSES, Molasses, or *Melasses*, that grofs, yet fluid matter remaining of fugar, after refining, and which no boiling will bring to a confiftence more folid than that of fyrup; hence alfo called *fyrup of fugar*.

In the manufacture of fugar in the Weft Indies, the moloffes, not improperly called the treacle of fugar, is obtained by the following procefs. The curing-houfe, which is a large airy building, is provided with a capacious moloffes ciftern, the fides of which are floped and lined with tarras or boards. Over this ciftern there is a frame of maffy joift work without boarding. On the joifts of this frame empty hogfheads without headings are ranged. In the bottoms of thefe hogfheads eight or ten holes are bored, through each of which the ftalk of a plantain leaf is thruft, fix or eight inches below the joifts, and which is long enough to ftand upright above the top of the hogfhead. Into thefe hogfheads, the mafs from the cooler is put, which is called *potting*; and the moloffes drains through the fpongy ftalk and drops into the ciftern, from which it is occafionally taken for diftillation. For other particulars, fee the article Sugar; and particularly the method of *claying* fugar.

The term *molaffes* has been ufed to denote the fediment of one kind of fugar called *chypre*, or brown fugar, which is the refufe of other fugars not to be whitened, or reduced into loaves. (See Sugar.) Moloffes have been much ufed in Holland among poor people, for the preparation of tobacco, and alfo inftead of fugar.

Molosses, *Artificial.* There has been found a method of making moloffes from apples, without the addition of fugar. The apple that fucceeds beft in this operation is the fummer-fweeting of a middle fize, pleafant to the tafte, and fo full of juice, that feven bufhels will yield a barrel of cyder. The manner of making it is this: the apples are to be ground and preffed, then the juice is to be boiled in a large copper till three quarters of it be evaporated: this will be done with a moderate fire in about fix hours, with the quantity of juice above mentioned; by this time it will be of the confiftence and tafte as well as the colour of moloffes.

This new moloffes ferves to all the purpofes of the common kind, and is of great ufe in preferving cyder. Two quarts of it put into a barrel of racked cyder, will preferve it, and give it an agreeable colour.

The invention of this kind of moloffes was owing to Mr. Chandler, of Woodftock, in New England, who living at a diftance from the fea, and where the common moloffes was very dear and fcarce, provided this for the fupply of his own family, and foon made the practice general among the people of the neighbourhood. It is to be obferved, that this fort of apple, the fweeting, is of great ufe in making cyder, one of the very beft kinds we know being made of it. The people in New England alfo feed their hogs with the fallings of their orchards of thefe apples; and the confequence of this is, that their pork is the fineft in the world. Phil. Tranf N° 374. p. 230.

Molosses *Spirit*, a very clean and pure fpirit, much ufed in England, and made from moloffes or common treacle diffolved in water, and fermented in the fame manner as malt or the common malt-fpirit. If fome particular art is not ufed in the making of this, it will not prove fo vinous as the malt-fpirit, but more flat and lefs pungent and acid, though otherwife much cleaner tafted, as its effential oil is of a lefs naufeous flavour. Whence if good frefh wine leys, abounding

in tartar, be duly fermented in the ſolution made thin for that purpoſe, the ſpirit will by that means become much more vinous and briſk, and approach more to the nature of the foreign ſpirits.

After the firſt diſtilling of moloſſes ſpirits from the waſh into low wines, it is to be rectified, and in the ſucceeding rectifications proper additions are to be made. Alkaline ſalts, ſo common in the rectifying of the malt-ſpirits, muſt be avoided in this caſe, as not at all ſuiting this ſpirit, and the neutral ones only muſt be uſed, ſuch as ſandiver, common decrepitated ſalt, ſal enixum Paracelſi, and the like; but upon the whole nothing ſo conſiderable is to be expected from theſe ſalts, as from a careful rectification in balneo Mariæ, without any other admixture; by this alone repeated two or three times with freſh water each time, the ſpirit will at once be made fit for the niceſt uſes.

Where the moloſſes ſpirit is brought to the common proof-ſtrength, if it be found not to have enough of the vinoſity in it, it will be very proper to add to it ſome good ſpiritus nitri dulcis; and if the ſpirit be clean worked, it may by this addition alone be made to paſs on ordinary judgments for French brandy.

When newly diſtilled, this ſpirit, like all others, is colourleſs, and limpid as water; but our diſtillers always give it the ſame ſort of yellow tinge, which the foreign ſpirits are found to obtain from the caſks in which they are ſent over. They have many ways of giving this colour extempore; but the two moſt in uſe are, either by an extract of oak-wood, or by burnt ſugar.

Moloſſes ſpirit being occaſionally dearer than that of malt, it is frequently met with baſely adulterated with a mixture of that ſpirit, and indeed ſeldom is to be bought without ſome daſh of it. Many have a way of mixing malt in the fermenting liquor; by this the yield of the whole is greatly increaſed, and the maker may aſſure the buyer that the ſpirit is pure as it ran from the worm.

England is the principal place where this ſpirit is made at this time: it was at one time prepared in great quantities in France, eſpecially on the river Loire; but it has been forbidden there under a ſevere penalty. In Holland alſo they have it not, on account of the high duty laid upon treacle in favour of their own ſugar-bakers.

We meet with very little of moloſſes ſpirit reduced to the ſtrength of alcohol or ſpirit of wine, though, when rectified to this ſtate in a proper manner, it is very little inferior to the real alcohol of wine, the name of which is ſo well known among us, though the thing itſelf is perhaps never ſeen here. All that we call ſpirit of wine being no other than malt ſpirit reduced to an imperfect alcohol, or a ſpirit almoſt totally inflammable.

Great quantities of moloſſes ſpirit are uſed in the adulterating of brandy, rum, and arrack; and great quantities are uſed alone in the making of cherry-brandy and other drams by infuſion, in all which many prefer it even to the foreign ſpirits.

In moſt of the nice caſes in our compound diſtillery, the moloſſes ſpirit ſupplies the place of a pure and clean malt-ſpirit, which we have not yet the way of producing in the large way to advantage. Our cinnamon, citron, and other fine cordial waters, are made with it; for the malt ſpirit would give theſe a very diſagreeable flavour.

There is alſo another uſe to which this ſpirit ſerves extremely well, and in which even a foreign ſpirit that has any remarkable flavour will not do ſo well; this is the making of the extemporaneous wine, which ſome people are ſo fond of. See *Extemporaneous* WINE.

It gives a yellow ſtain to the hands, or other ſubſtances dipped into it: and may therefore be of uſe in dyeing. It is poſſible alſo, that the vinegar-makers may find uſe for it in their way; but the moſt advantageous of all its uſes is to the diſtiller himſelf, a quantity of it added to new treacle intended for fermentation will be of great uſe in the proceſs, and increaſe very conſiderably the quantity of ſpirit; but the proportion in regard to the new matter muſt not be too great. Shaw's Eſſay on Diſtillery.

For the method of extracting ſpirits from moloſſes in the Weſt Indies, ſee the article RUM.